

The Use of Hyperspectral Sounding Radiances for Climate Analyses – Experience with AIRS

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² NASA/LaRC (SSAI)

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Objective

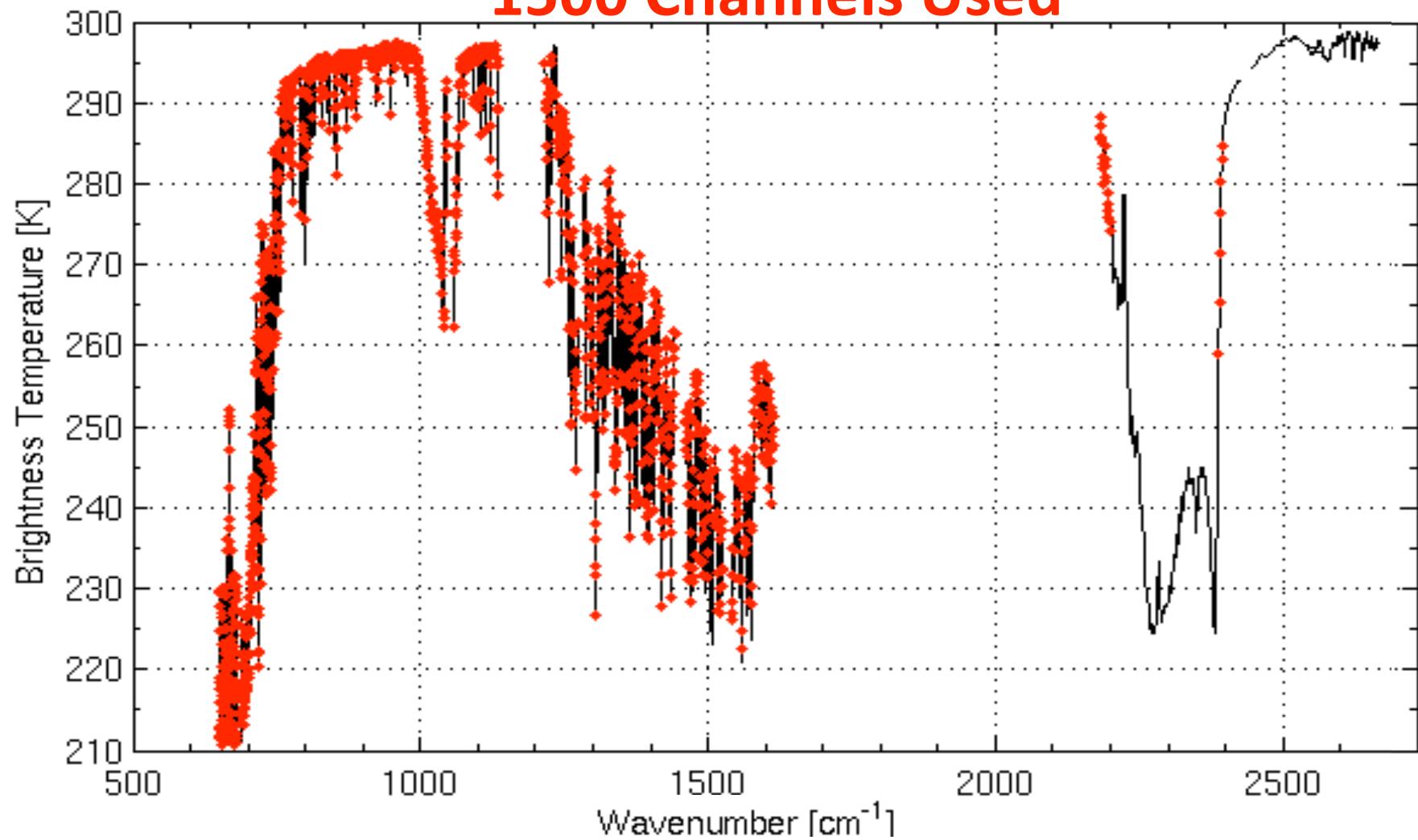
- Develop and test a “Single Field-of-View” climate variable retrieval method which can be applied to low horizontal resolution (e.g., 100-km) hyperspectral satellite data (e.g., IRIS and CLARREO) as well as high spatial resolution (e.g., 13-km) operational hyperspectral sounder (e.g., AIRS, IASI, CrIS) radiance observations, in order to obtain algorithm independent assessments of climate change.
- Test this algorithm using 6-years (2003-2008) AIRS radiance data
- Validate this algorithm using ECMWF (ERA-Interim) re-analyses of global observing system (satellite plus conventional) data and intercomparing the 100-km FOV product with that obtained from full resolution (13-km) AIRS data.

“Climate” Single FOV Technique

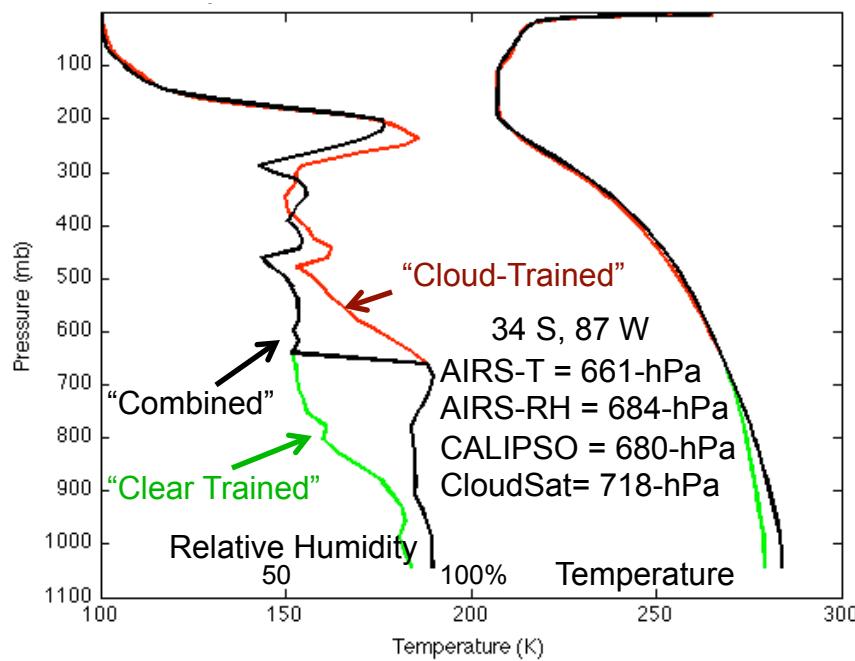
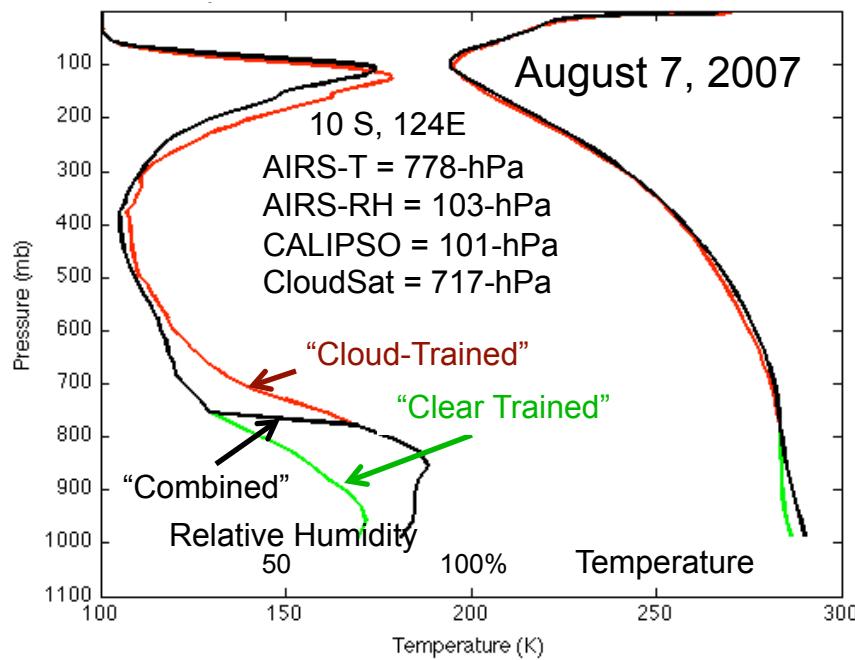
“Clear-trained” and “Cloud-trained” EOF regression IR hyperspectral sounder retrievals of: surface skin temperature, CO₂ concentration, cloud top altitude, effective cloud optical depth, and atmospheric temperature, moisture, and ozone profiles above the cloud and below thin or scattered cloud (i.e., cloud effective optical depth < 1.5 and a cloud induced temperature attenuation < 15 K).

1. *Cloud height: Level where “cloud-trained” temperature profile retrieval becomes systematically greater than the “clear-trained” temperature profile retrieval. (The Cloud-trained EOF regression solution coefficients are selected from a set of ten classes of cloud-height stratified 200-hPa overlapping layers. The proper class is determined using a non-linear (i.e., iterative) cloud pressure regression estimator. The initial value is determined using an unclassified by cloud height linear regression operator.)*
2. *Cloud optical depth: Estimated using classified EOF regression*
3. *Atmospheric profile:*
 - a) *above the cloud: “clear-trained” retrieval*
 - b) *below the cloud: “cloud-trained” retrieval*

1500 Channels Used



AIRS Cloud Height & T/RH Profile Examples



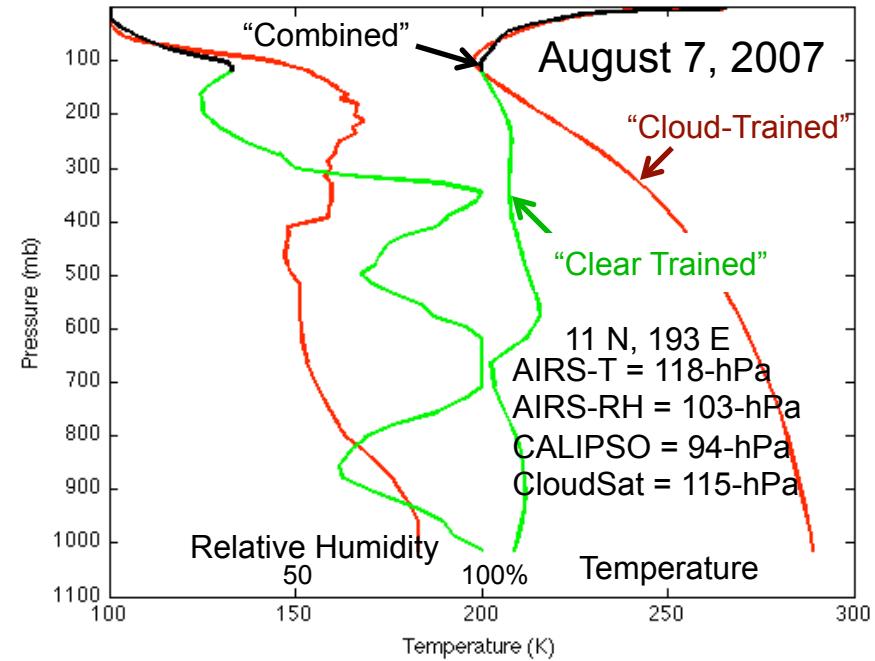
Cloud and Profile Determination:

- (1) T-cloud: Highest level where $T_{\text{cld}}(p) > T_{\text{clr}}(p)$ to the ground where $T_{\text{cld}}(p)$ & $T_{\text{clr}}(p)$ obtained by EOF regression
- (2) RH-cloud: Highest RH_{clr} peak $> 75\%$
- (3) Profile cloud height taken as (1) above
- (4) $T = T_{\text{clr}}$ & $RH = RH_{\text{clr}}$ above cloud
- (5) If [“Optical Depth” ≤ 1.5 & Max $[(T_{\text{cld}}(p) - T_{\text{clr}}(p))]$ $< 15\text{K}$ then the below cloud profiles are.:
 $T(p) = T_{\text{cld}}(p)$ and $RH(p) = RH_{\text{cld}}(p)$

Otherwise:

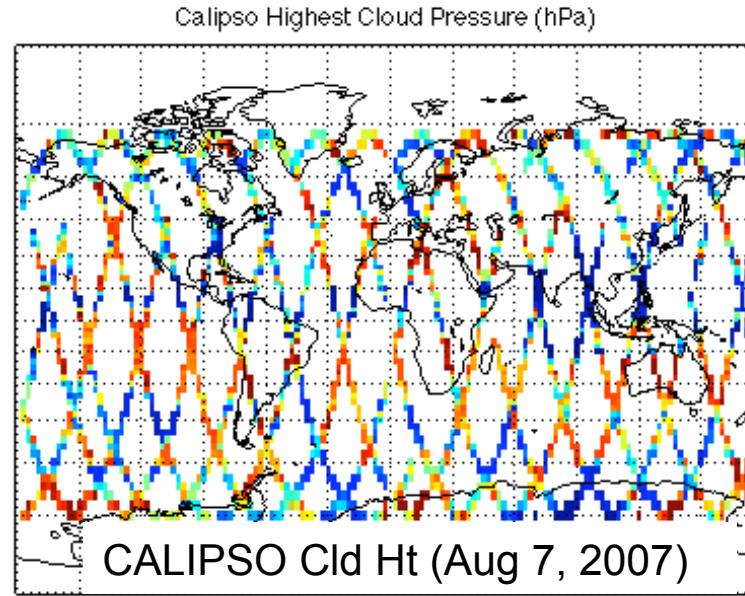
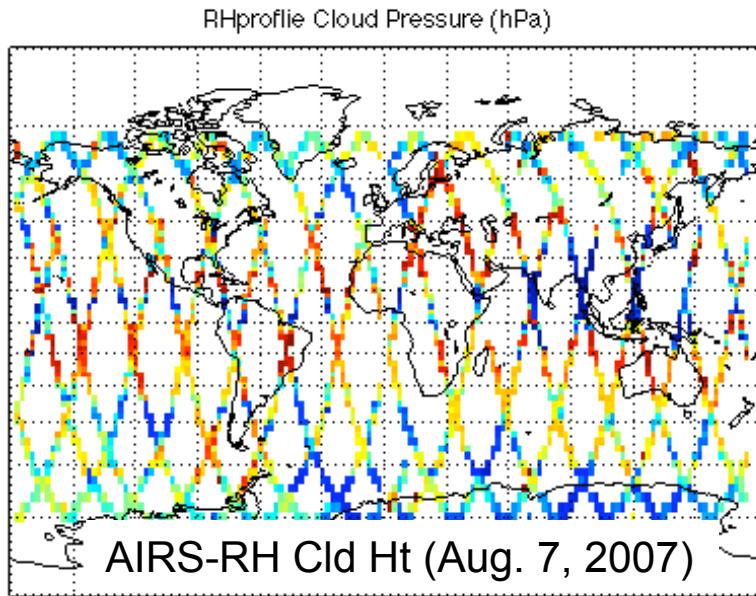
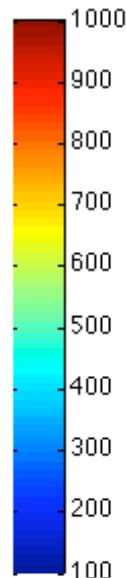
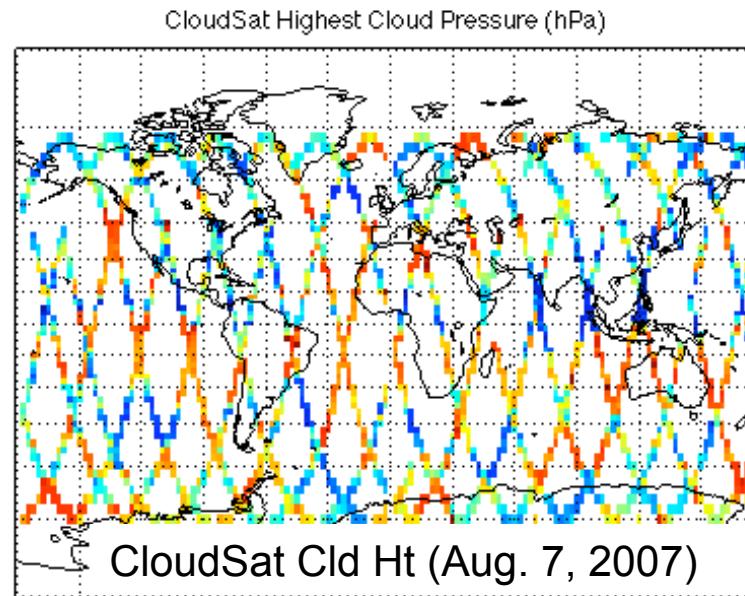
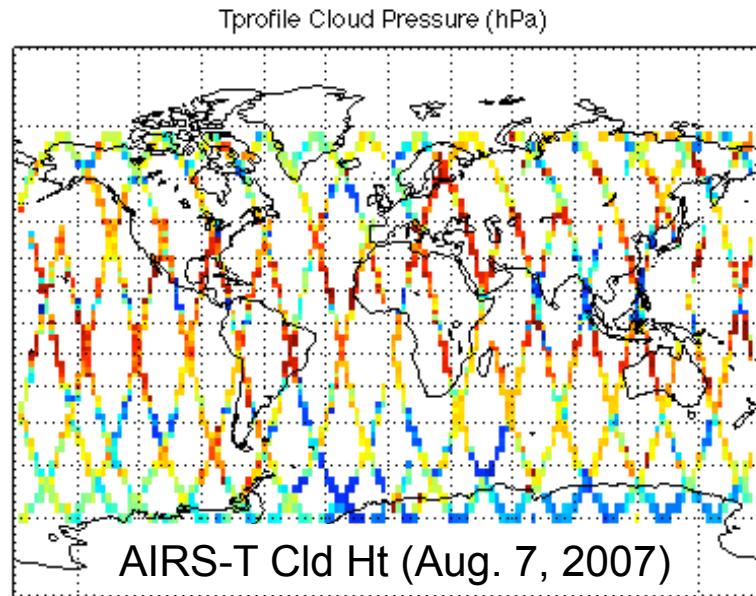
$T(p)$ & $RH(p)$ = “missing”

RH-profile senses optically thin cirrus
T-profile senses lower cloud



AIRS-T, AIRS-RH, CALIPSO, & CloudSat

Highest Co-located AIRS FOV Cloud Altitudes (2.5 deg. grid average)



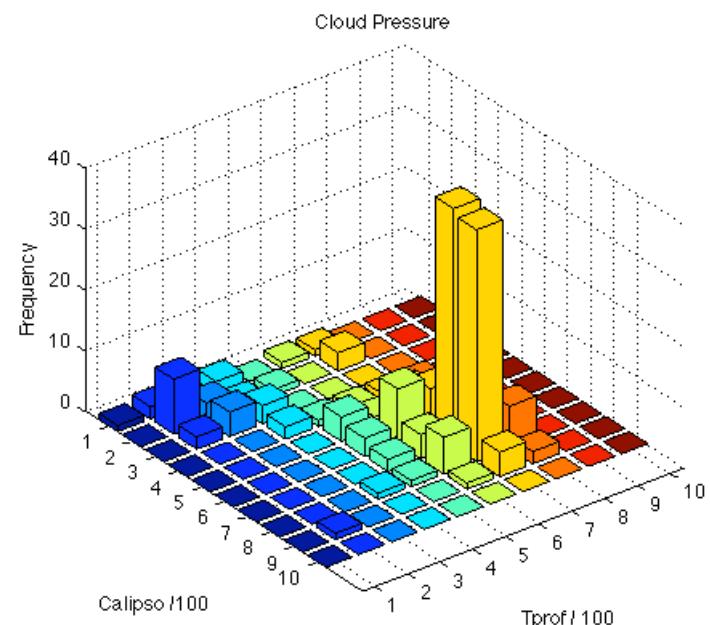
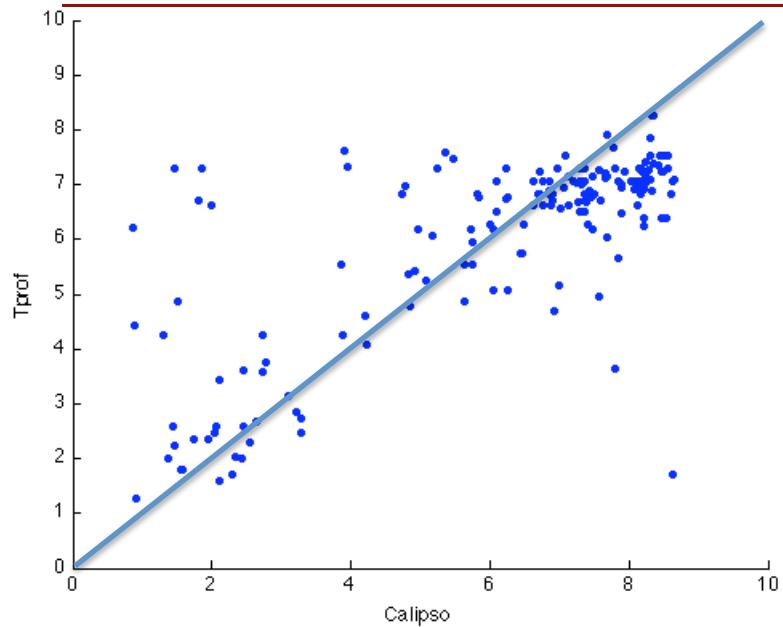
Inter-comparison Criteria

(AIRS, CALIPSO, and CloudSat co-located* fields of view)

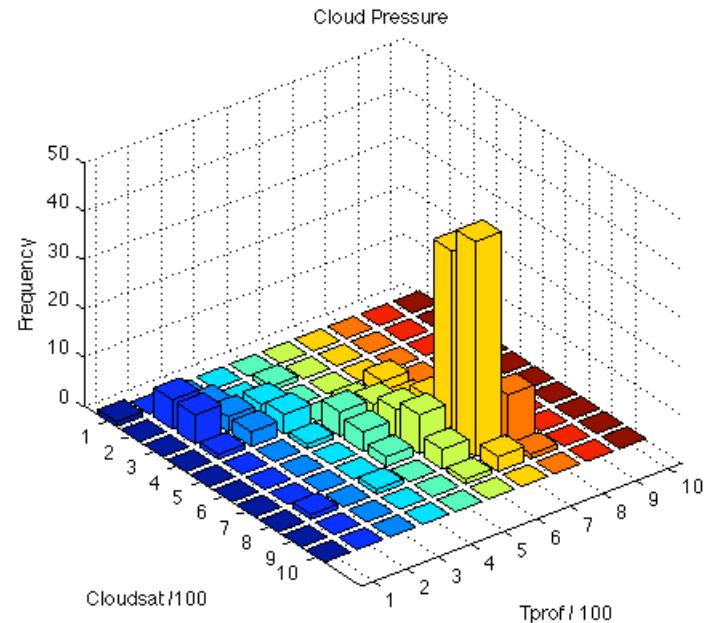
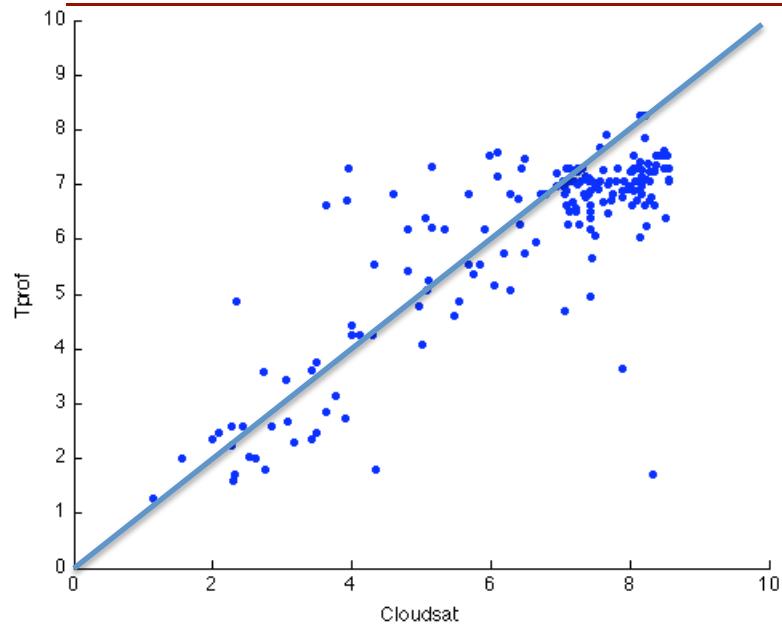
- MODIS Clear Probability = 0%
- IIR FOV average radiance difference $\leq 1 \%$
- CALIPSO Number of Cloud Layers ≤ 2

* Co-locations provided by Nagle and Holz (UW-CIMSS)

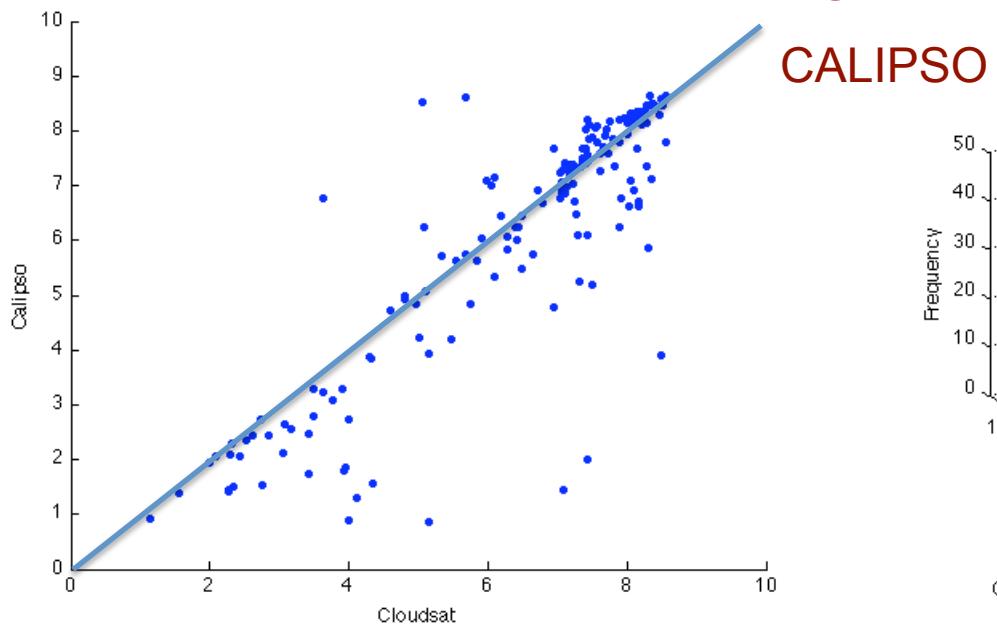
IR-Profile Vs CALIPSO Cloud Height



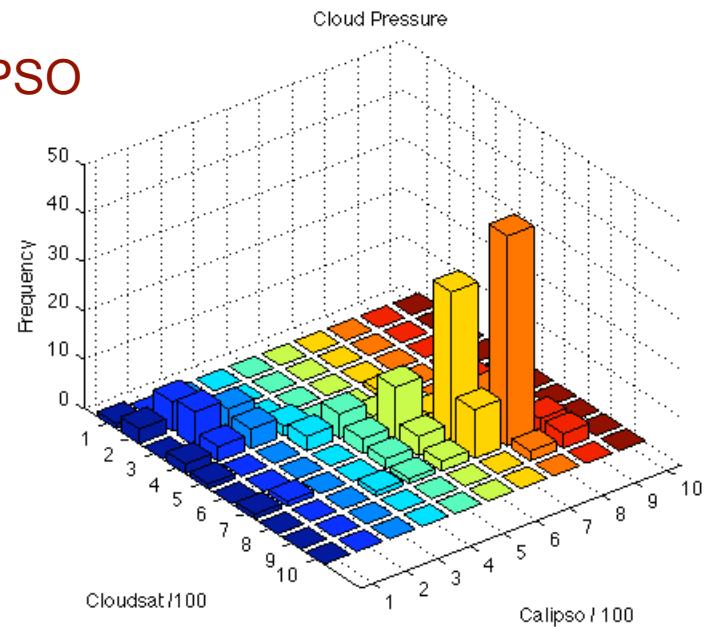
IR-Profile Vs CloudSat Cloud Height



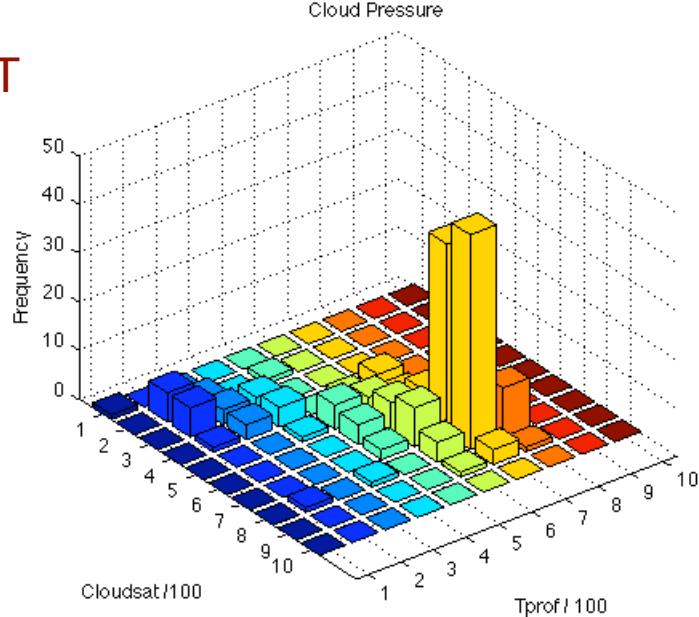
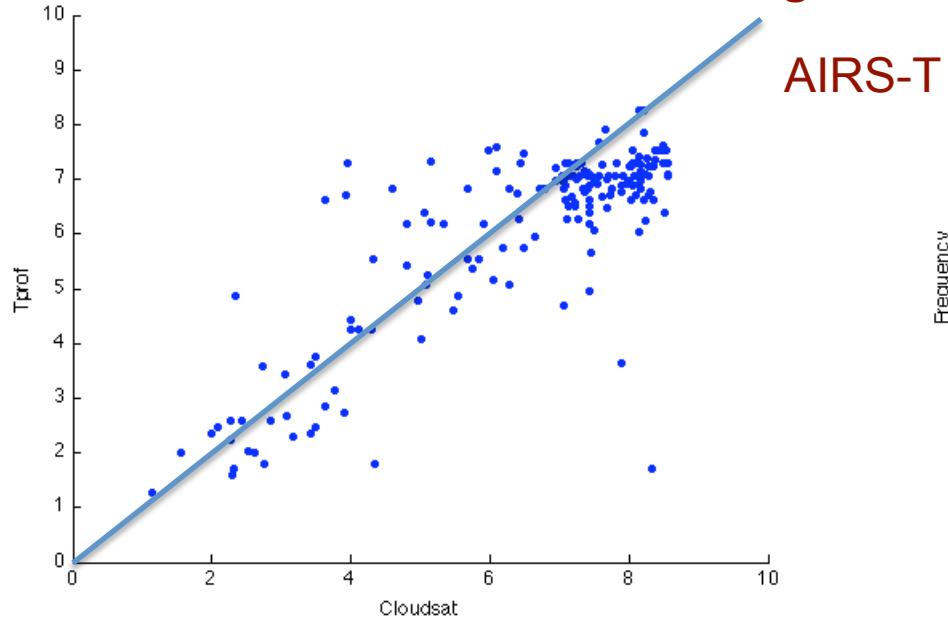
CALIPSO Vs CloudSat Cloud Height



Cloud Pressure



AIRS-T Vs CloudSat Cloud Height



(Nadir AIRS/"CLARREO" Vs ECMWF)

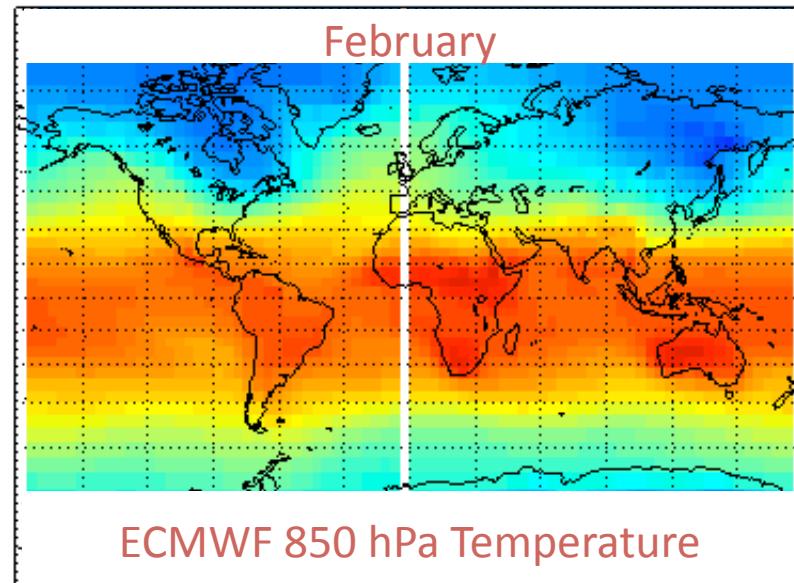
2003-2008 Monthly Mean
Temperature
and
Relative Humidity
for
February and August

Simulating “CLARREO” Data from AIRS

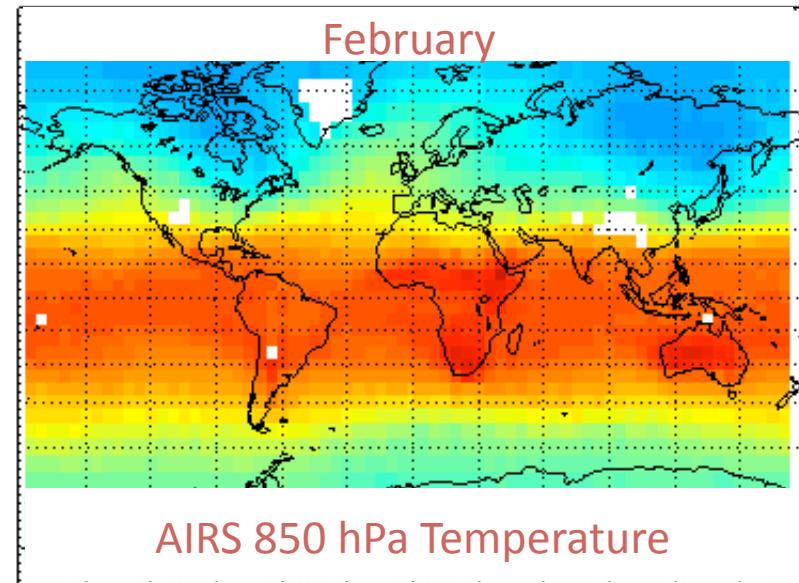
- Use Nadir-only samples
- “CLARREO” = 6 x 6 average (\approx 100-km resolution and spacing) AIRS Measurements
- “AIRS” = Clearest of six (\approx 13-km resolution and 100-km spacing)

850 hPa Temperature (2003-2008)

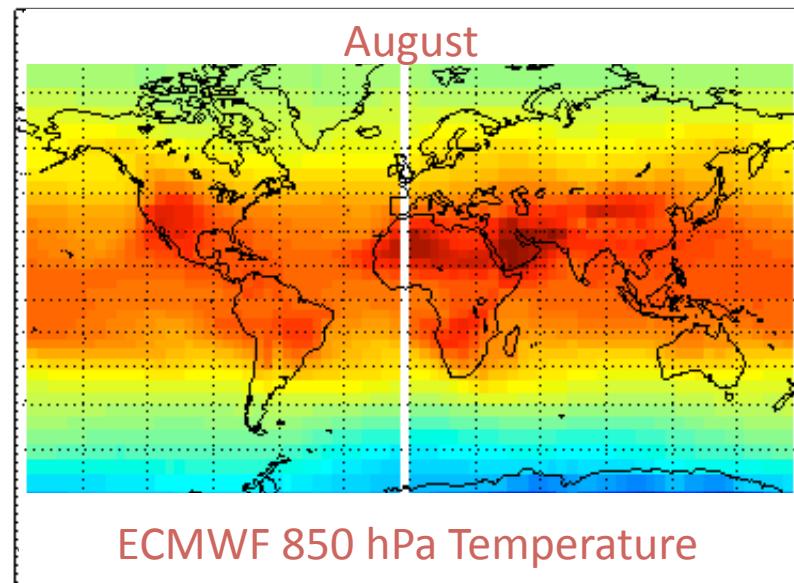
ECMWF Mean February 850 hPa Temperature



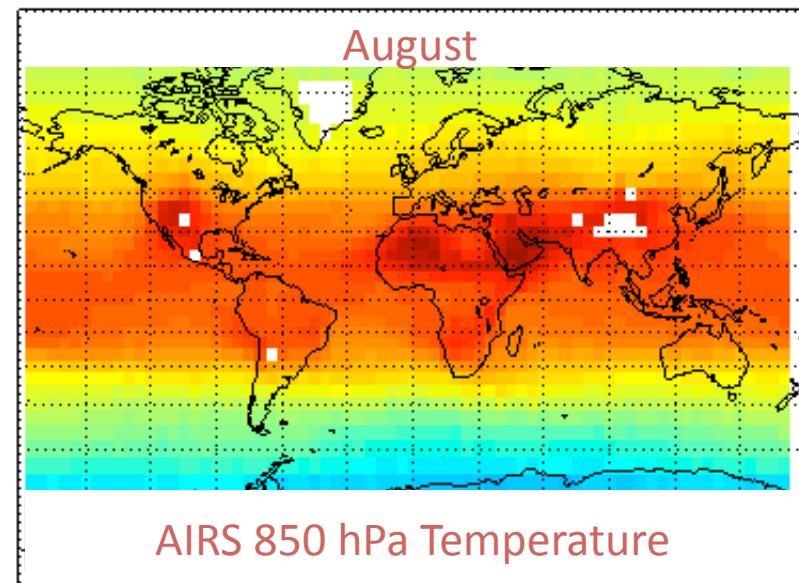
AIRS Mean February Temperature 853hPa



ECMWF Mean August 850 hPa Temperature

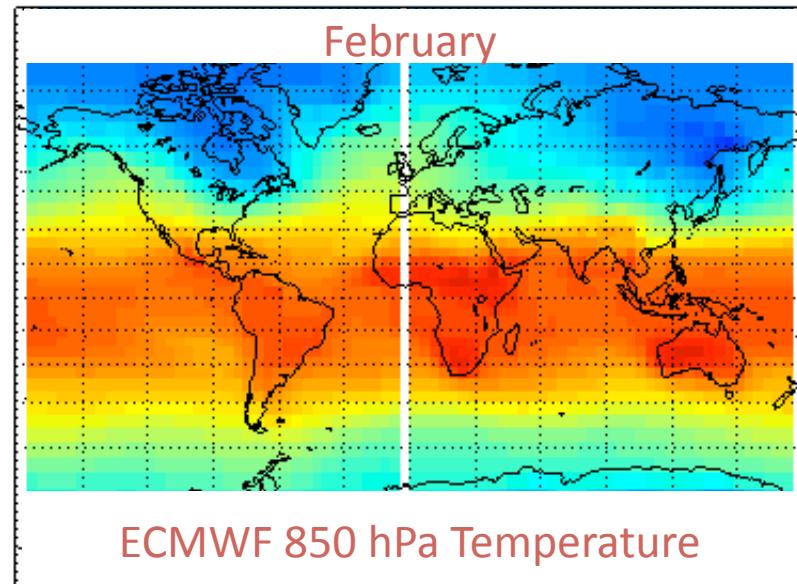


AIRS Mean August Temperature 853hPa

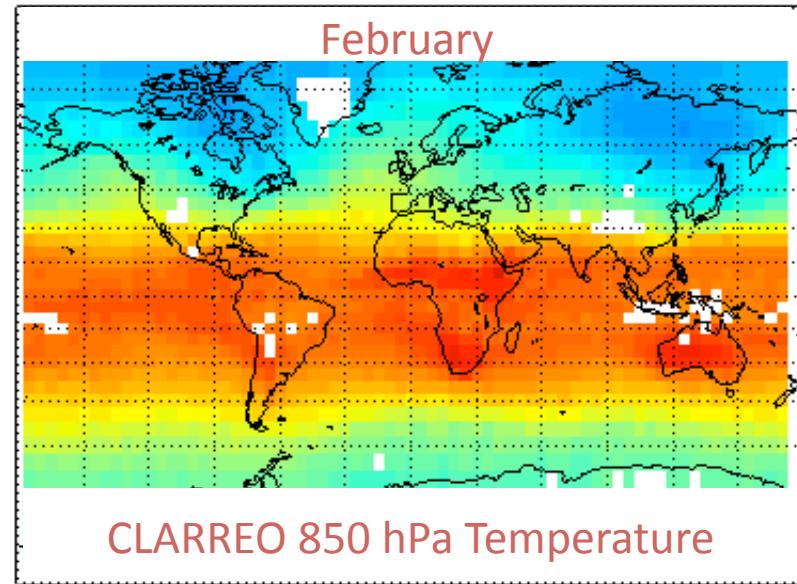


850 hPa Temperature (2003-2008)

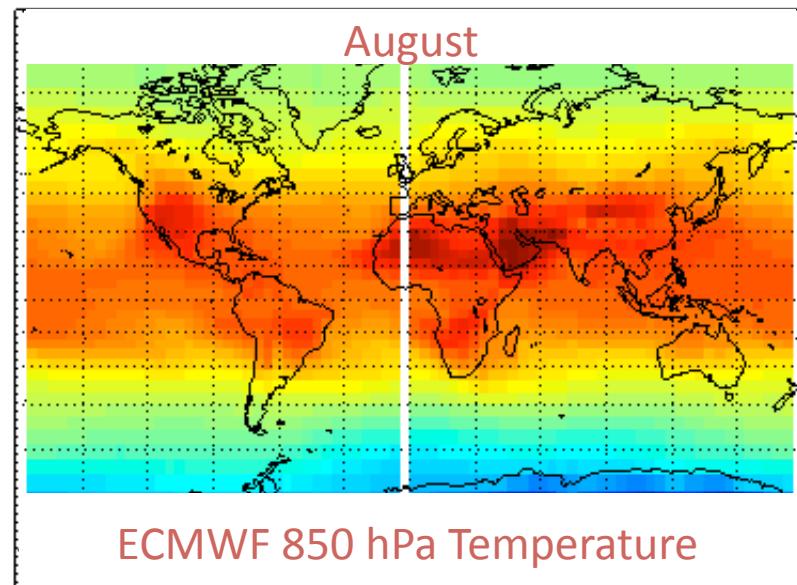
ECMWF Mean February 850 hPa Temperature



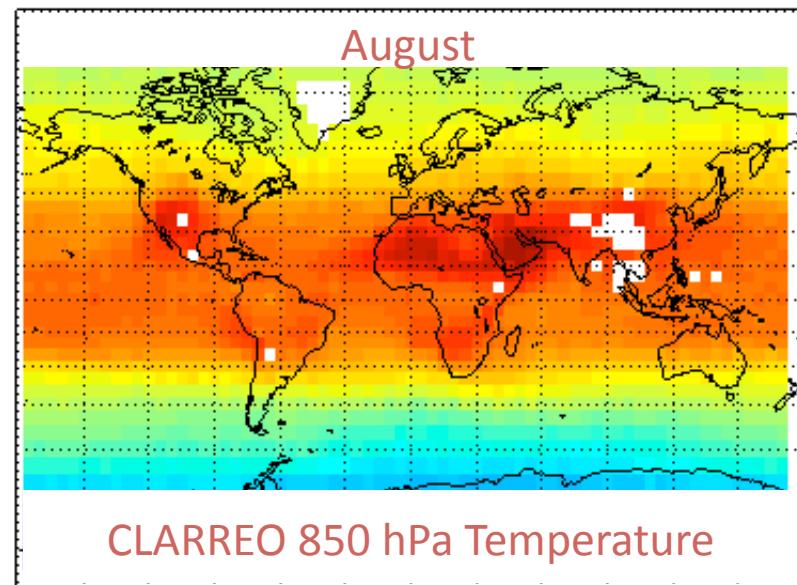
"CLARREO" Mean February Temperature 853hPa



ECMWF Mean August 850 hPa Temperature

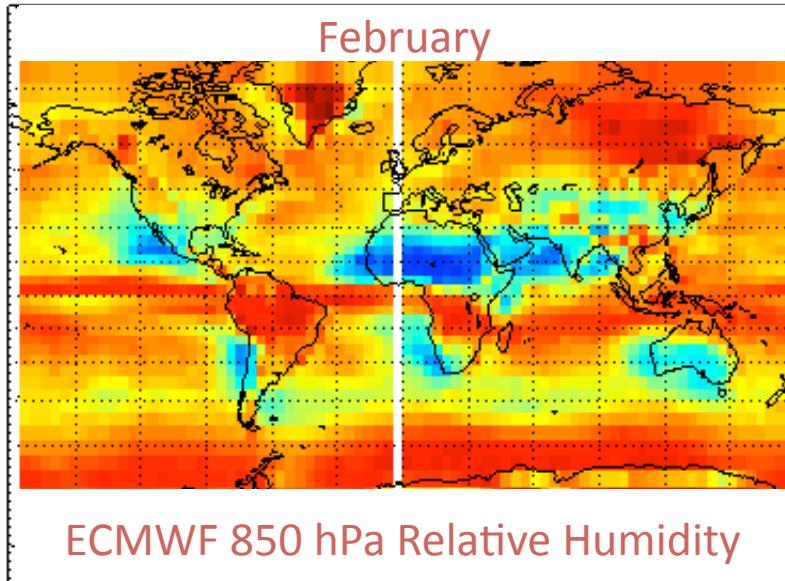


"CLARREO" Mean August Temperature 853hPa

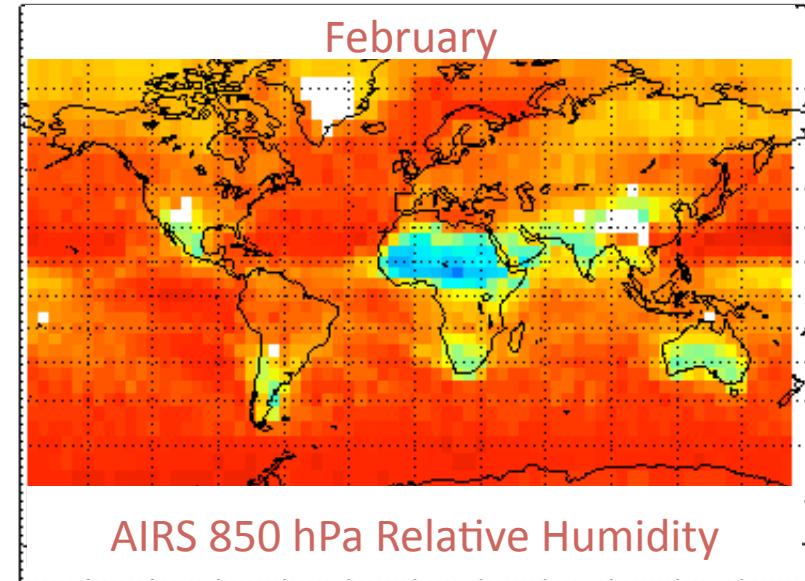


850 hPa Humidity (2003-2008)

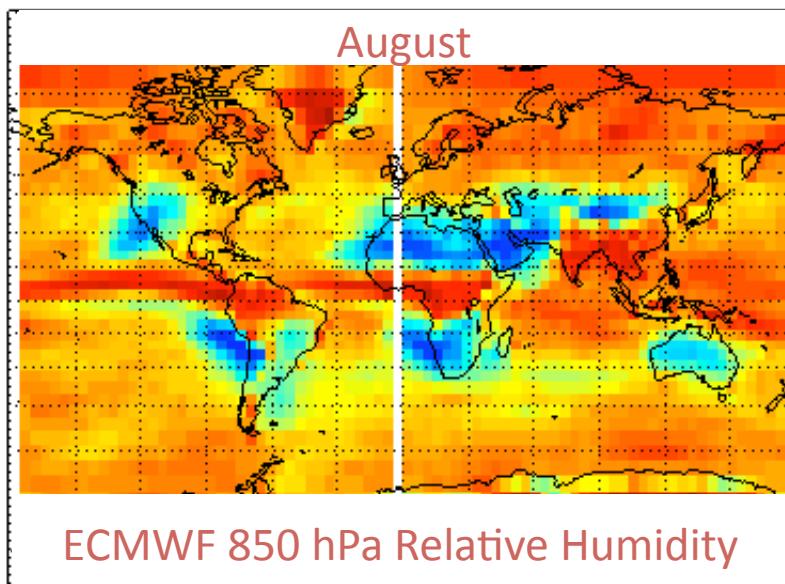
ECMWF Mean February 850 hPa Relative Humidity



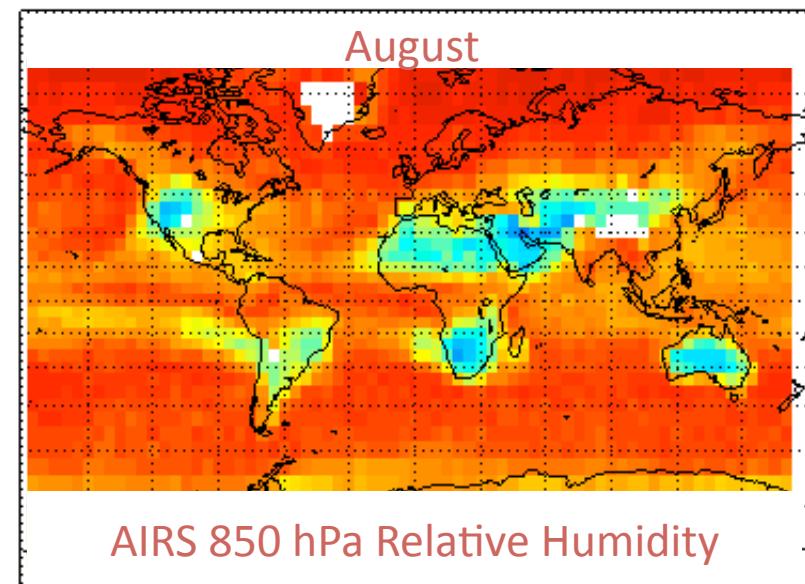
AIRS Mean February Humidity 853hPa



ECMWF Mean August 850 hPa Relative Humidity

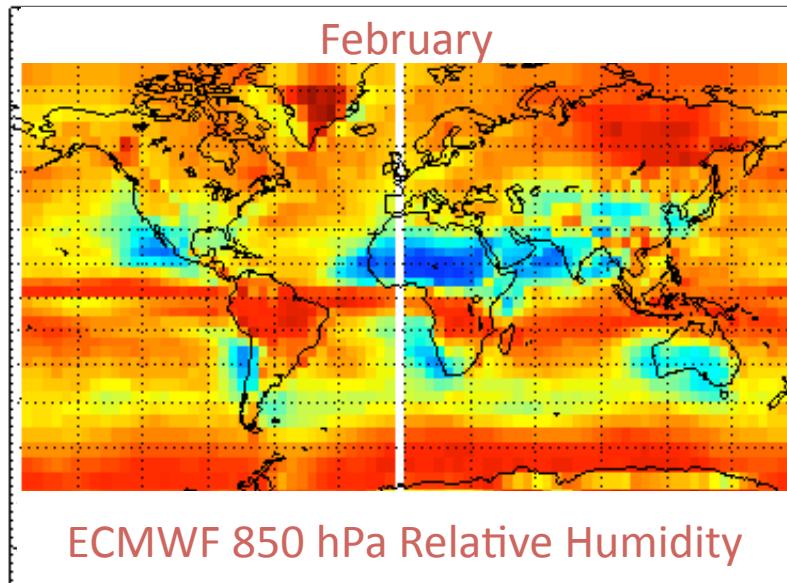


AIRS Mean August Humidity 853hPa

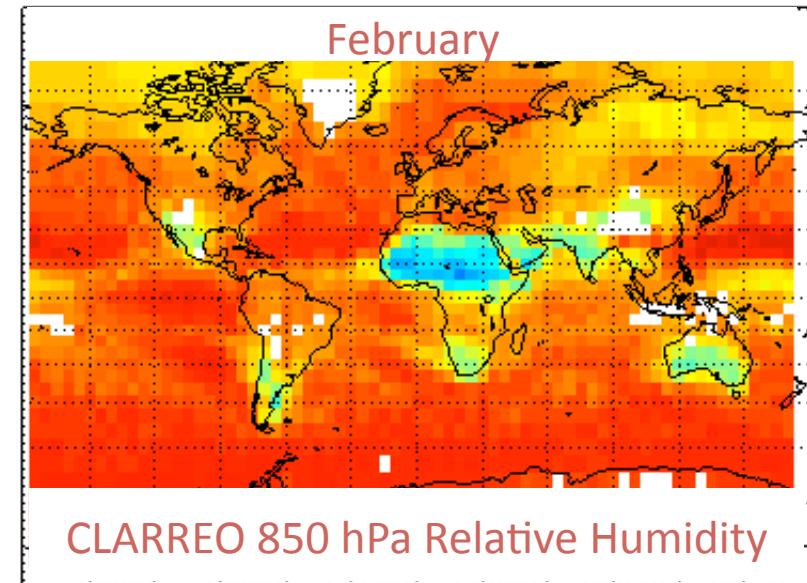


850 hPa Humidity (2003-2008)

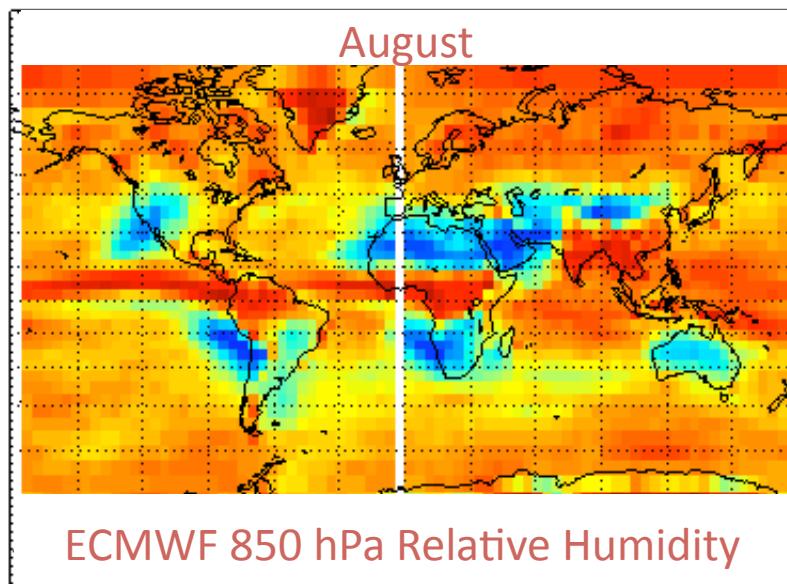
ECMWF Mean February 850 hPa Relative Humidity



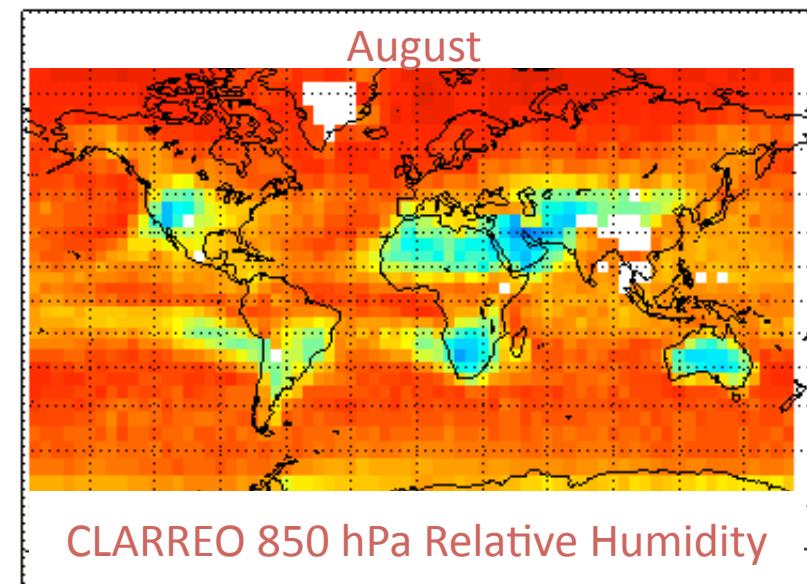
"CLARREO" Mean February Humidity 853hPa



ECMWF Mean August 850 hPa Relative Humidity

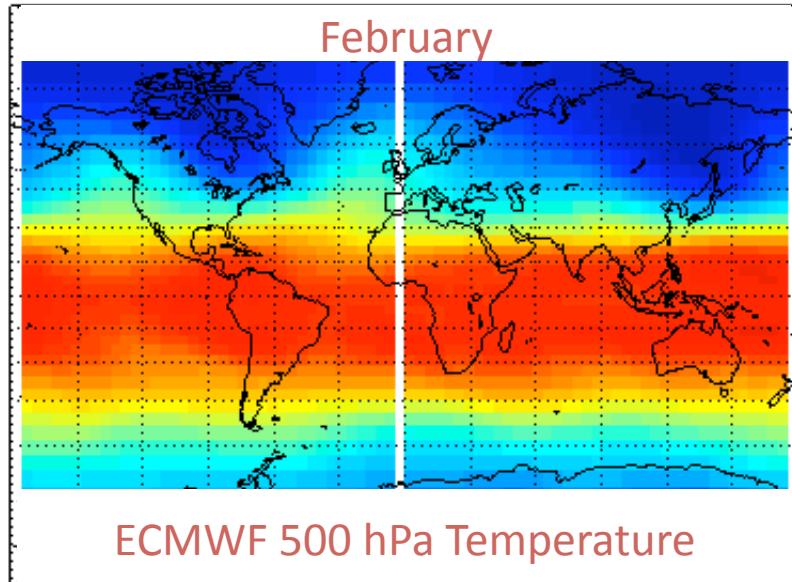


"CLARREO" Mean August Humidity 853hPa

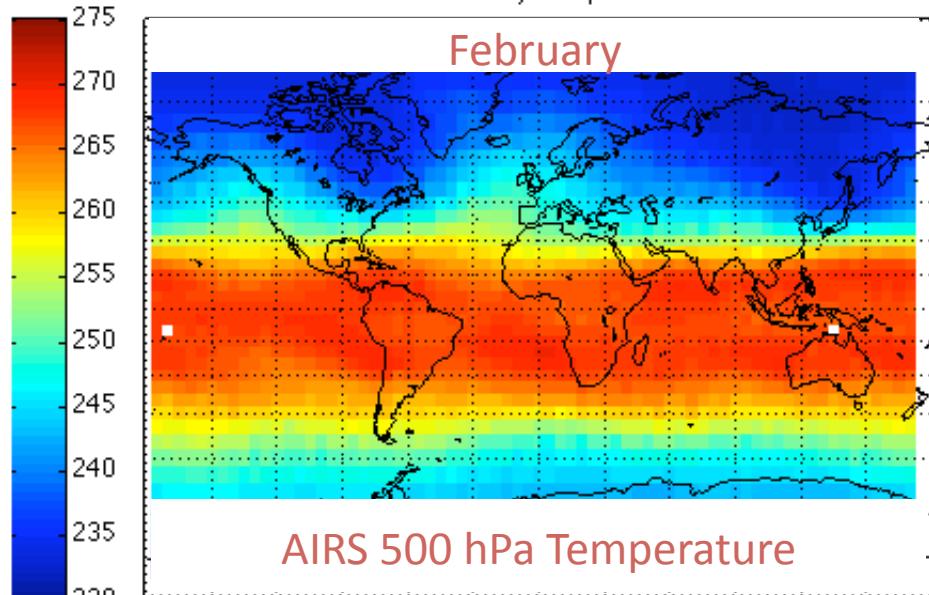


500 hPa Temperature (2003-2008)

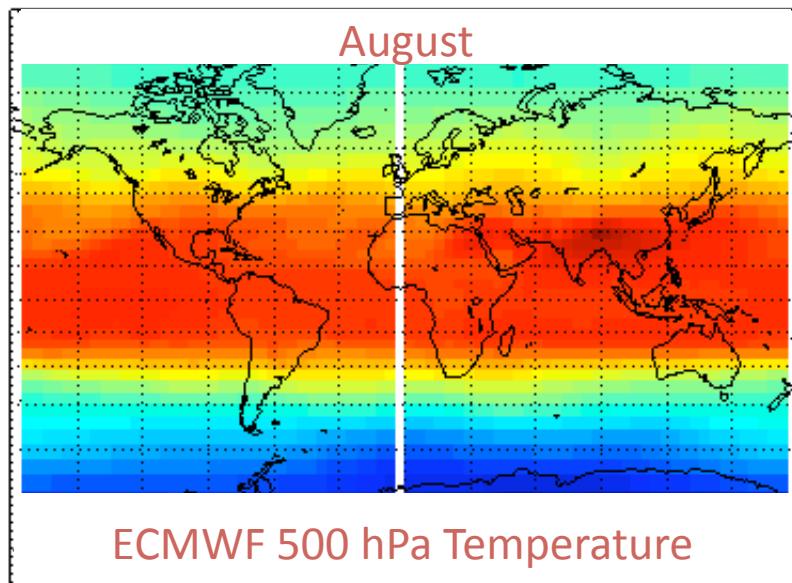
ECMWF Mean February 500 hPa Temperature



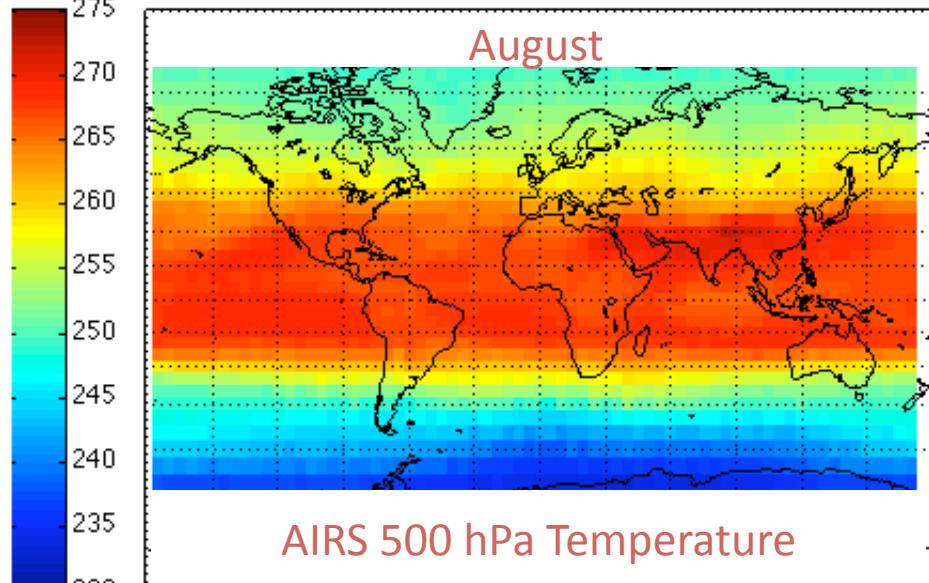
AIRS Mean February Temperature 497hPa



ECMWF Mean August 500 hPa Temperature

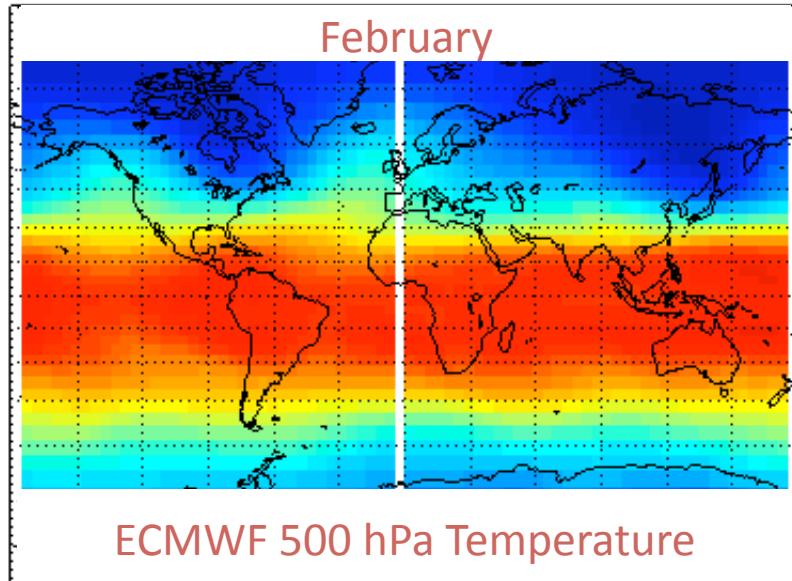


AIRS Mean August Temperature 497hPa

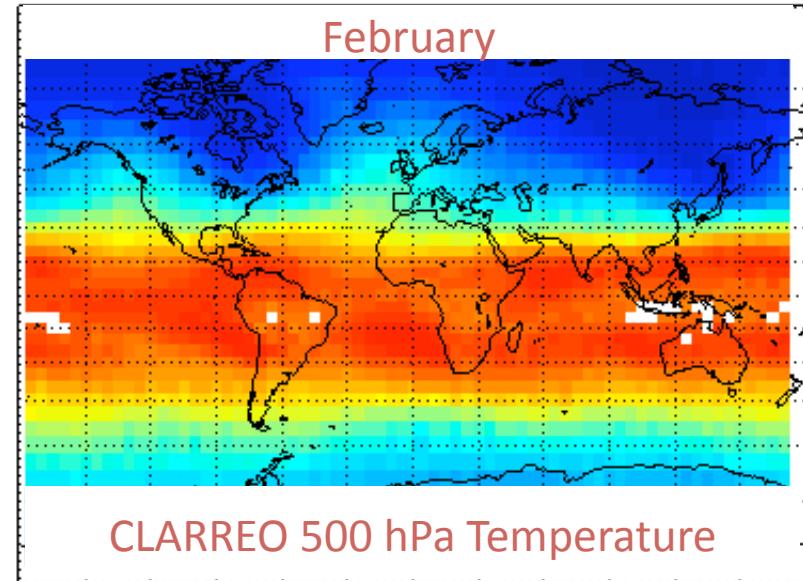


500 hPa Temperature (2003-2008)

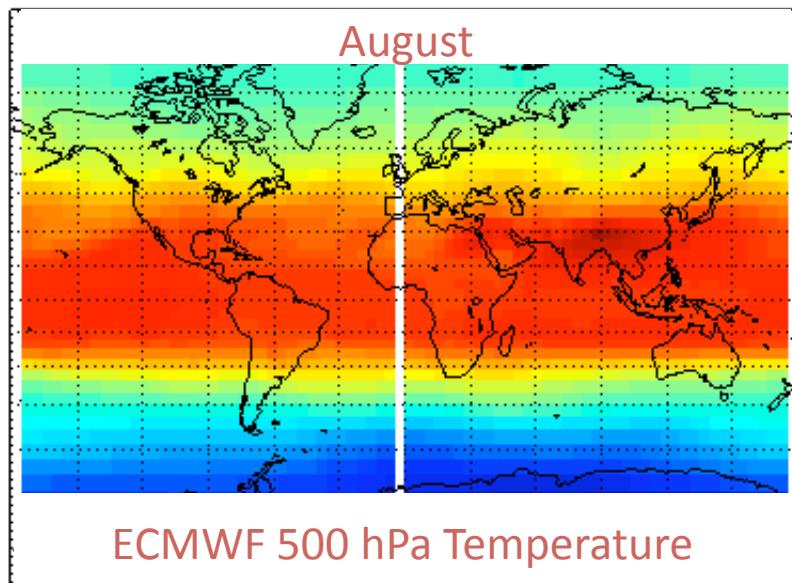
ECMWF Mean February 500 hPa Temperature



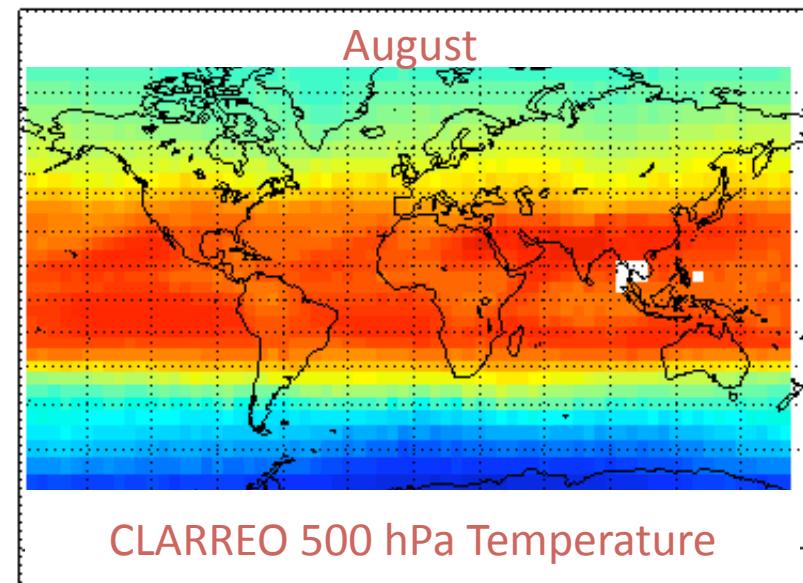
"CLARREO" Mean February Temperature 497hPa



ECMWF Mean August 500 hPa Temperature

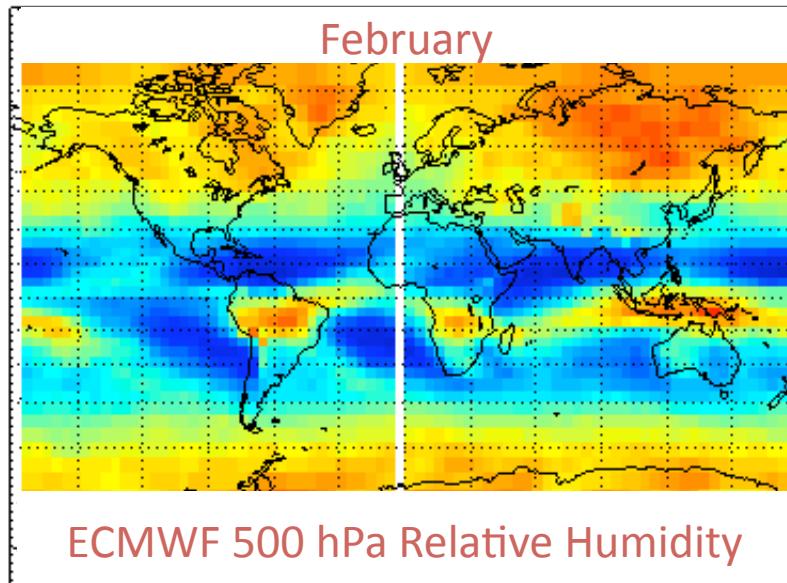


"CLARREO" Mean August Temperature 497hPa

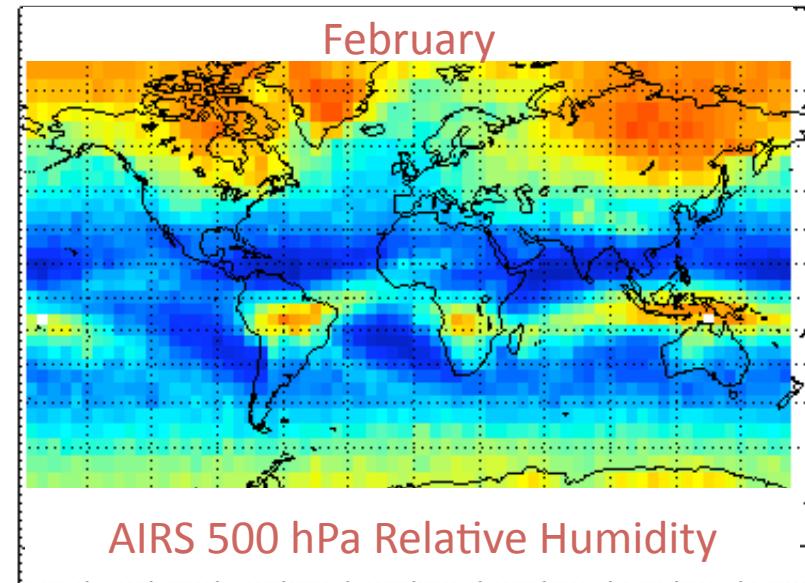


500 hPa Humidity (2003-2008)

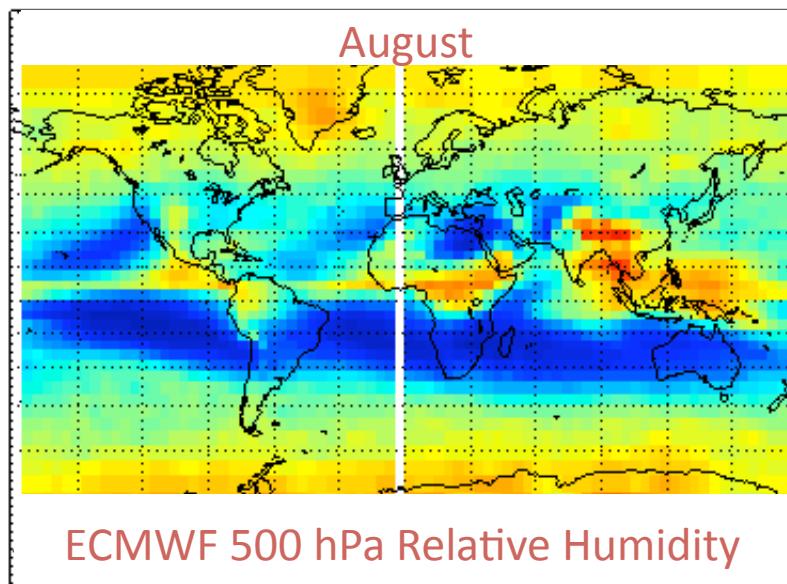
ECMWF Mean February 500 hPa Relative Humidity



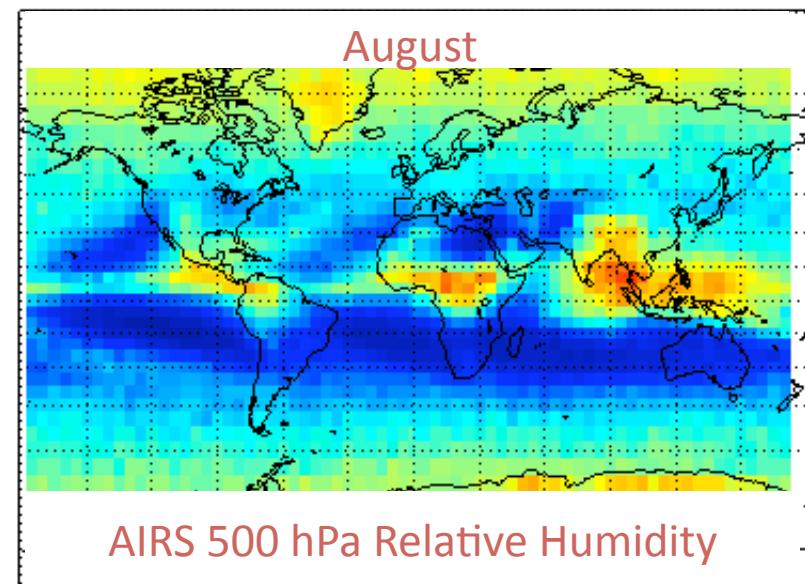
AIRS Mean February Humidity 497hPa



ECMWF Mean August 500 hPa Relative Humidity

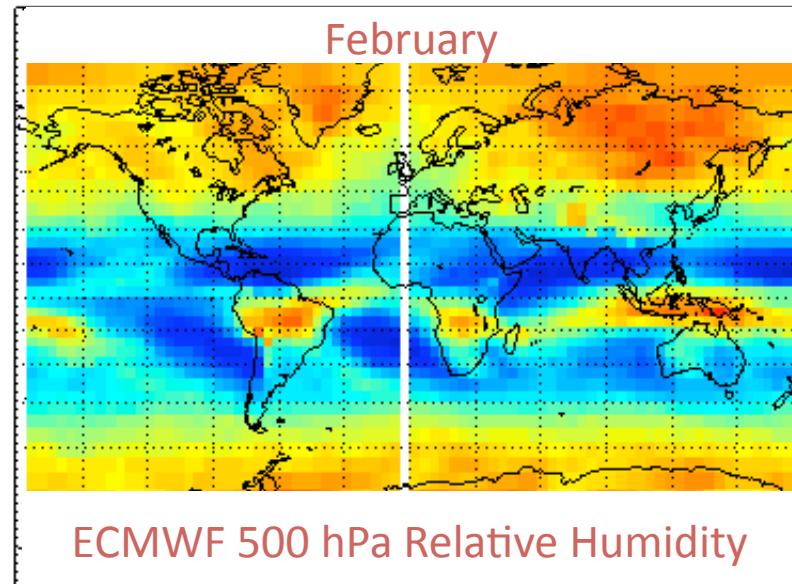


AIRS Mean August Humidity 497hPa

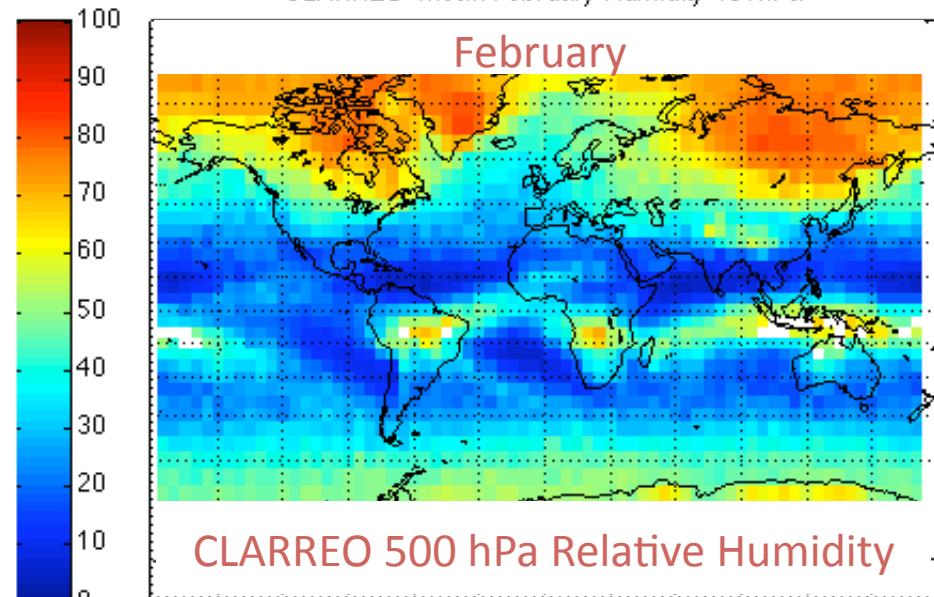


500 hPa Humidity (2003-2008)

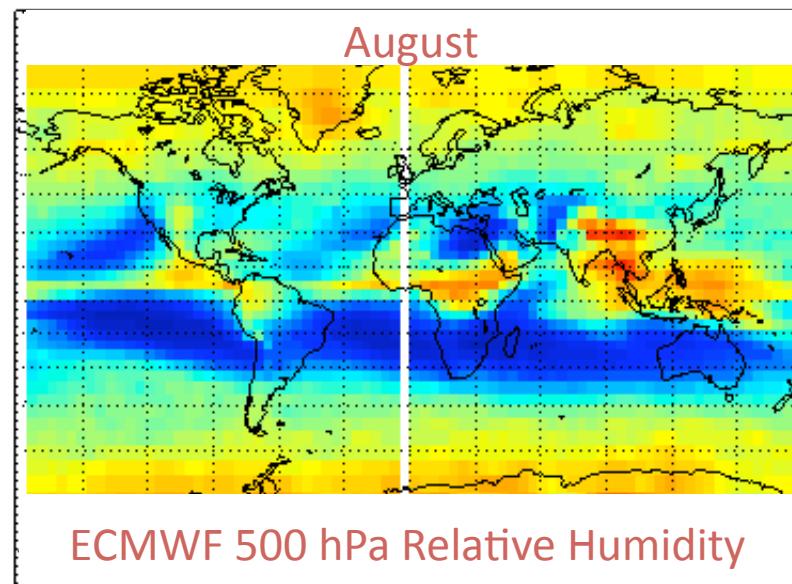
ECMWF Mean February 500 hPa Relative Humidity



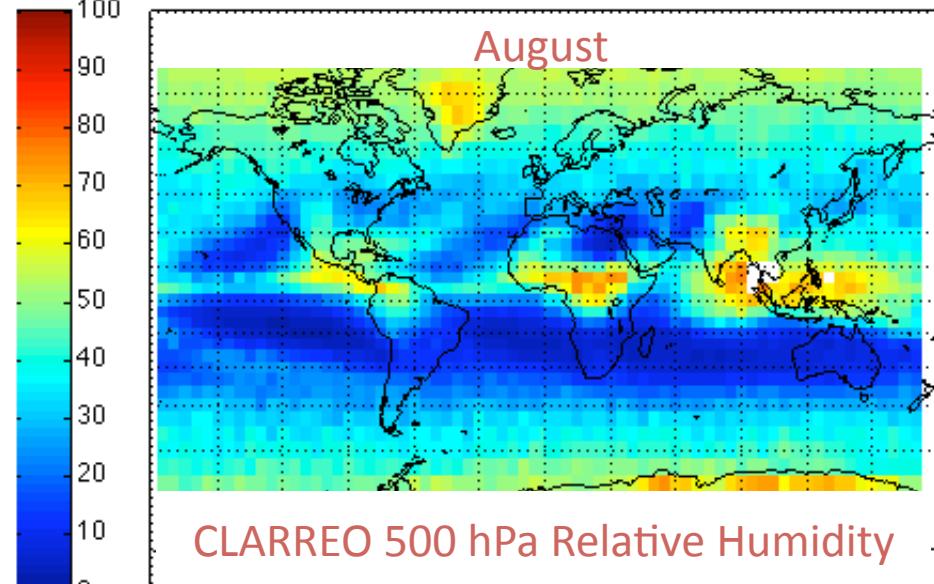
"CLARREO" Mean February Humidity 497hPa



ECMWF Mean August 500 hPa Relative Humidity

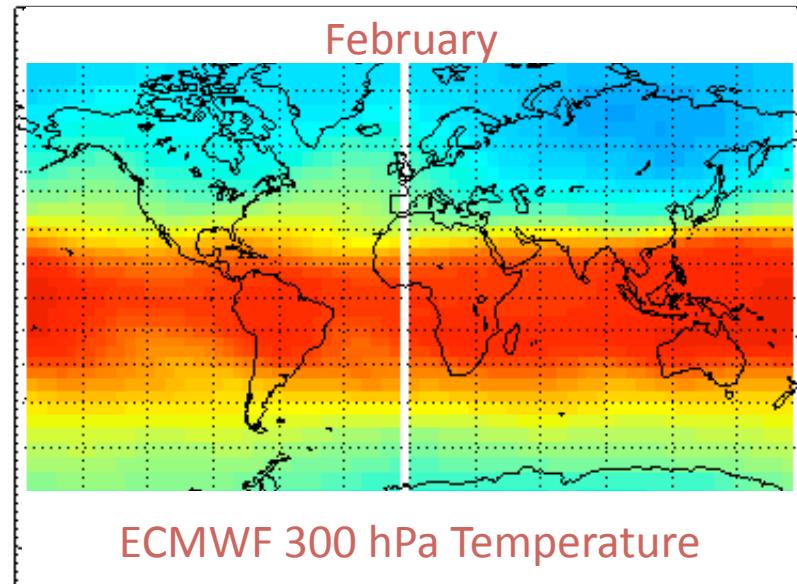


"CLARREO" Mean August Humidity 497hPa

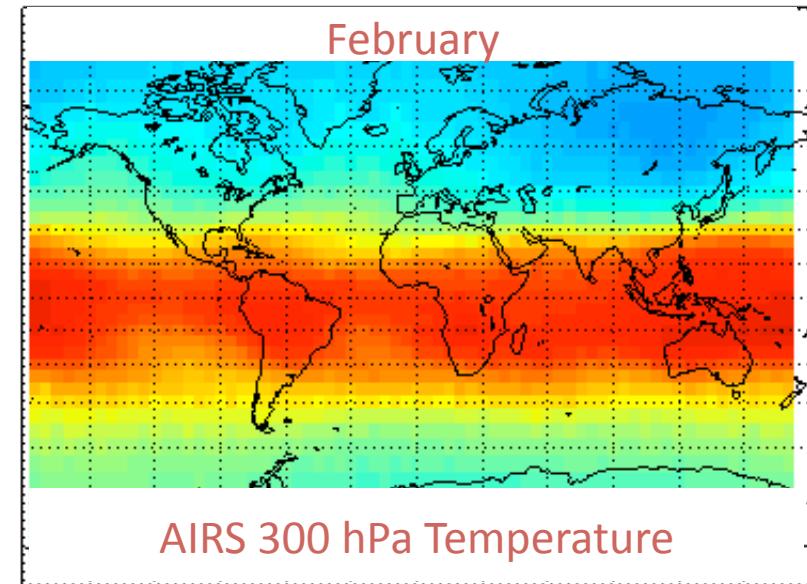


300 hPa Temperature (2003-2008)

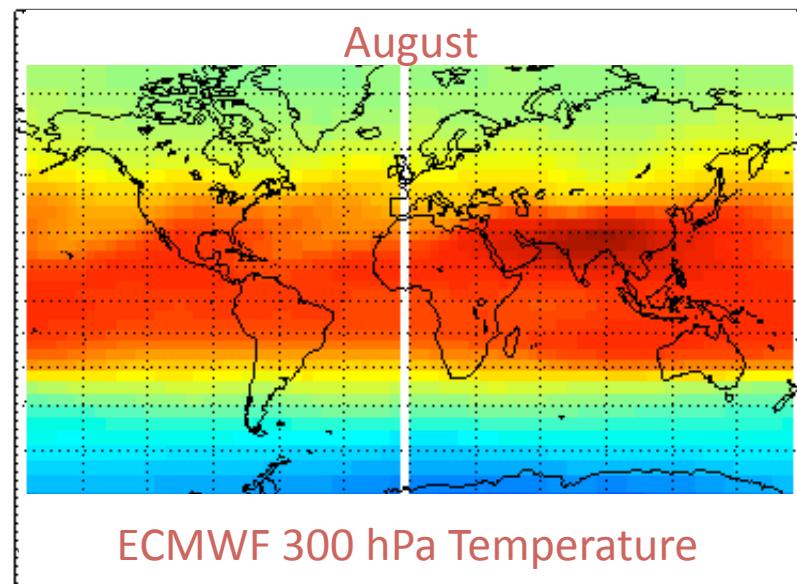
ECMWF Mean February 300 hPa Temperature



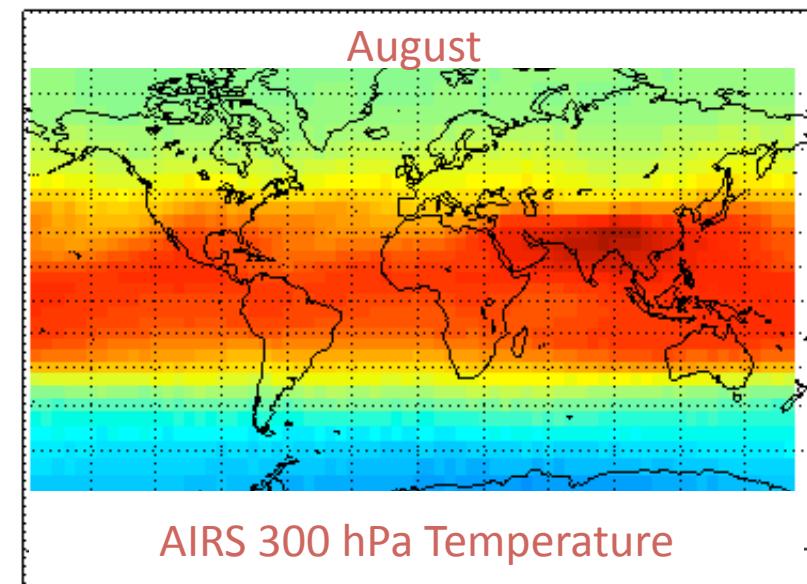
AIRS Mean February Temperature 300hPa



ECMWF Mean August 300 hPa Temperature

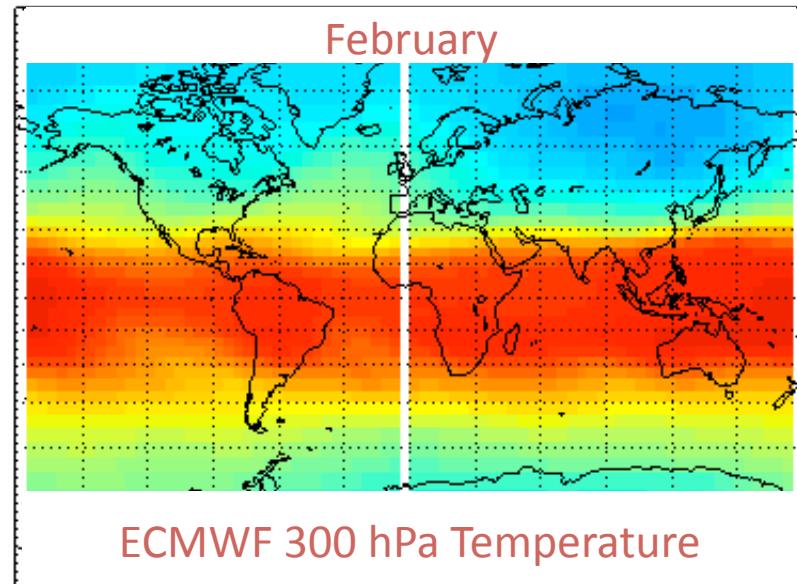


AIRS Mean August Temperature 300hPa

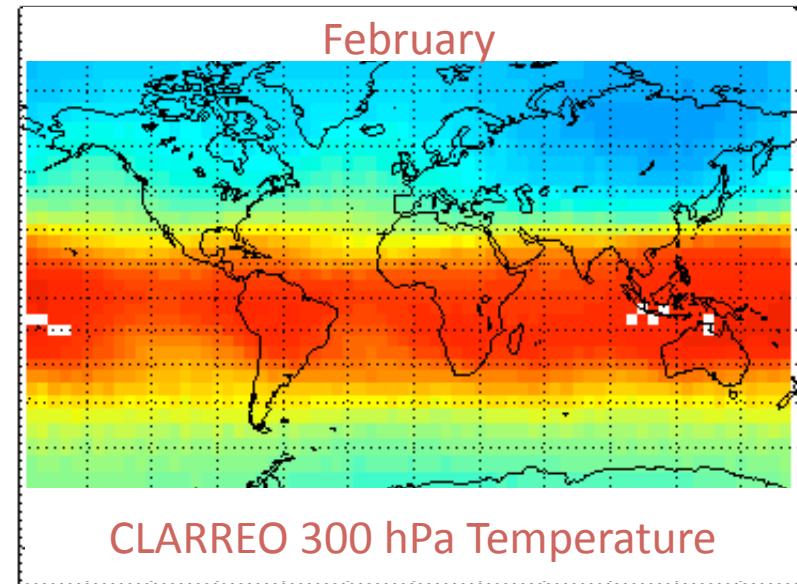


300 hPa Temperature (2003-2008)

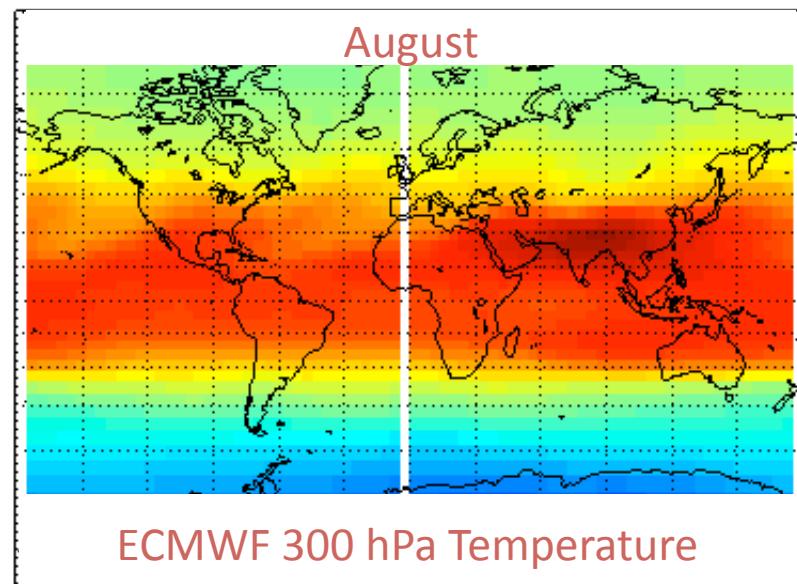
ECMWF Mean February 300 hPa Temperature



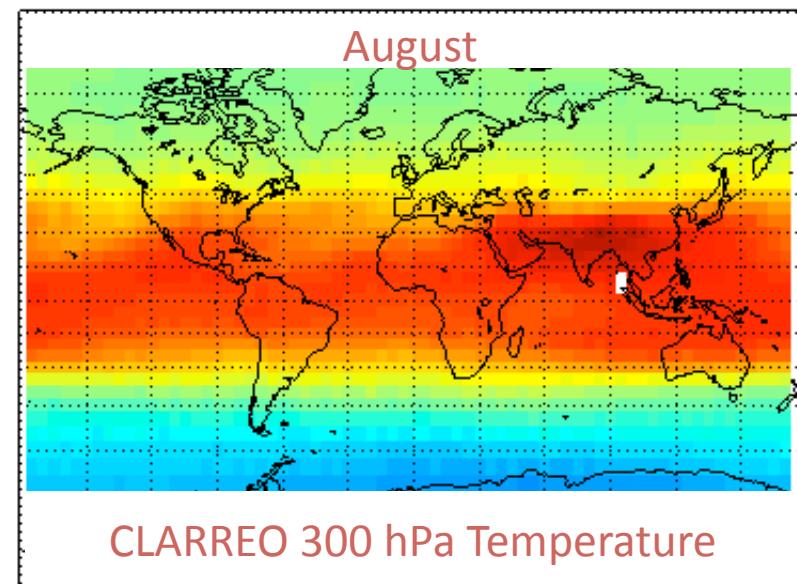
"CLARREO" Mean February Temperature 300hPa



ECMWF Mean August 300 hPa Temperature

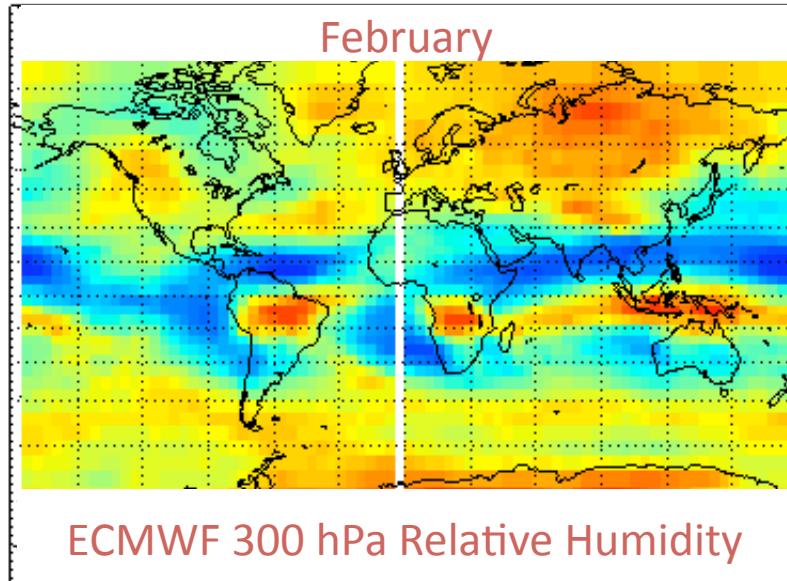


"CLARREO" Mean August Temperature 300hPa

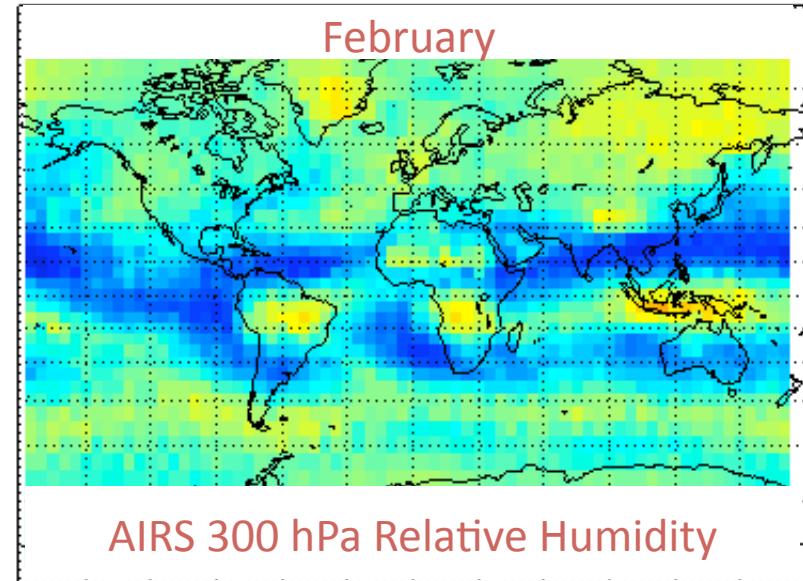


300 hPa Humidity (2003-2008)

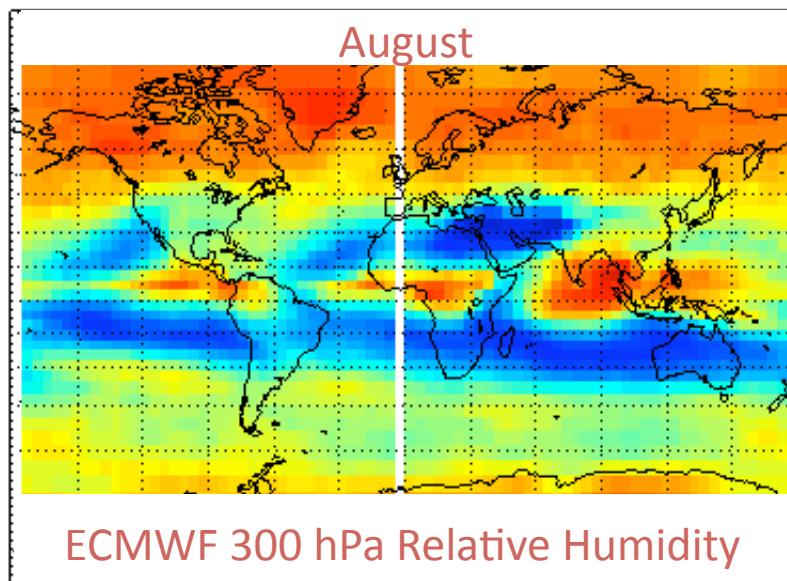
ECMWF Mean February 300 hPa Relative Humidity



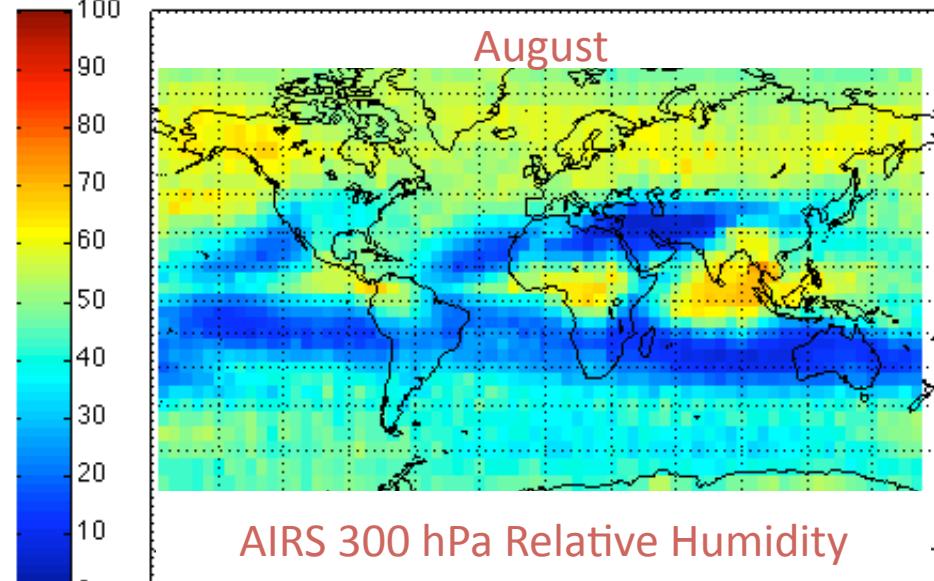
AIRS Mean February Humidity 300hPa



ECMWF Mean August 300 hPa Relative Humidity

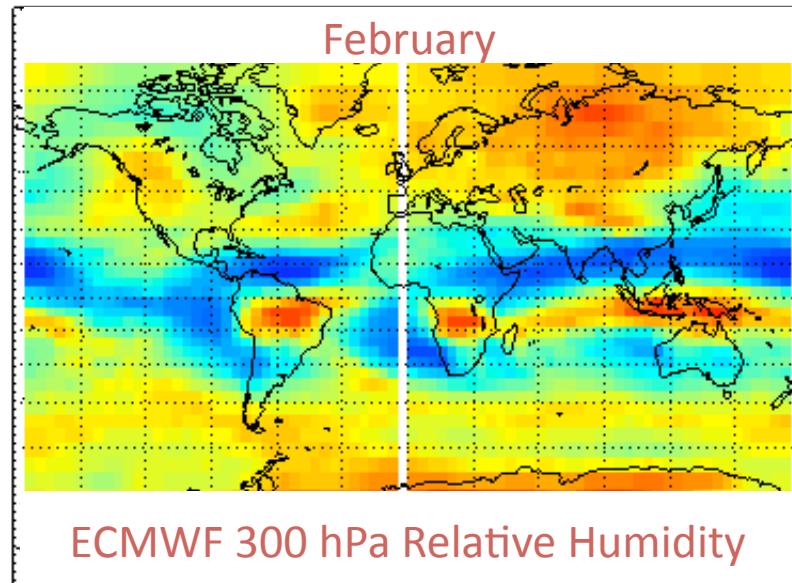


AIRS Mean August Humidity 300hPa

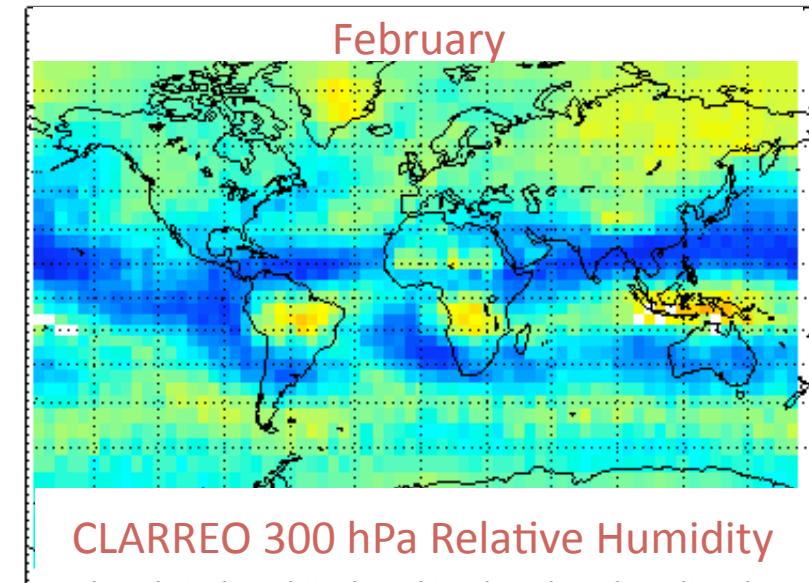


300 hPa Humidity (2003-2008)

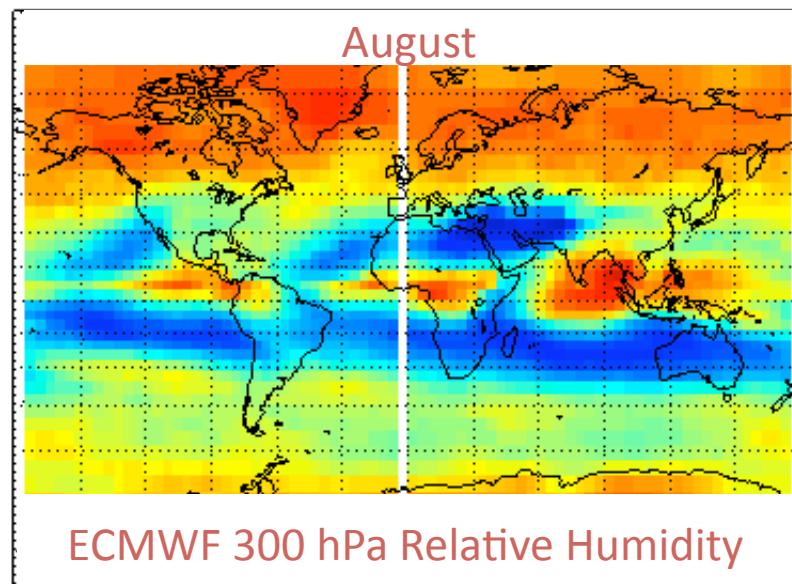
ECMWF Mean February 300 hPa Relative Humidity



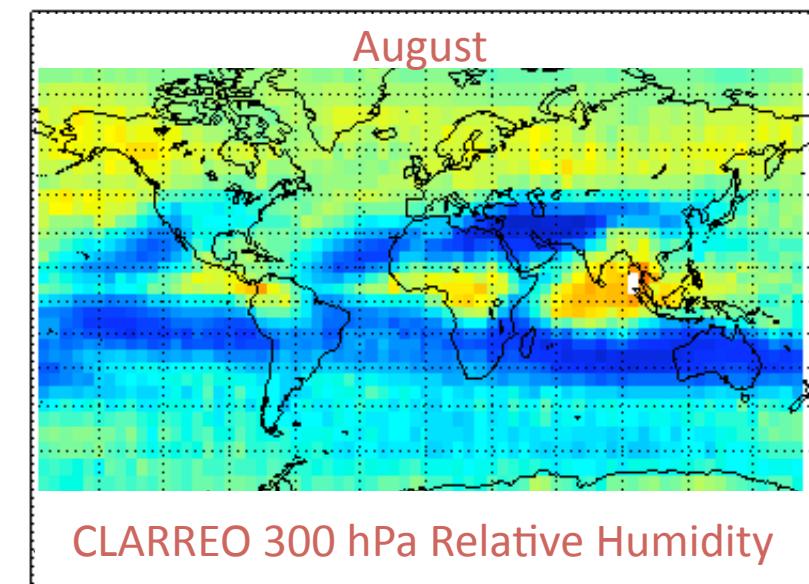
"CLARREO" Mean February Humidity 300hPa



ECMWF Mean August 300 hPa Relative Humidity

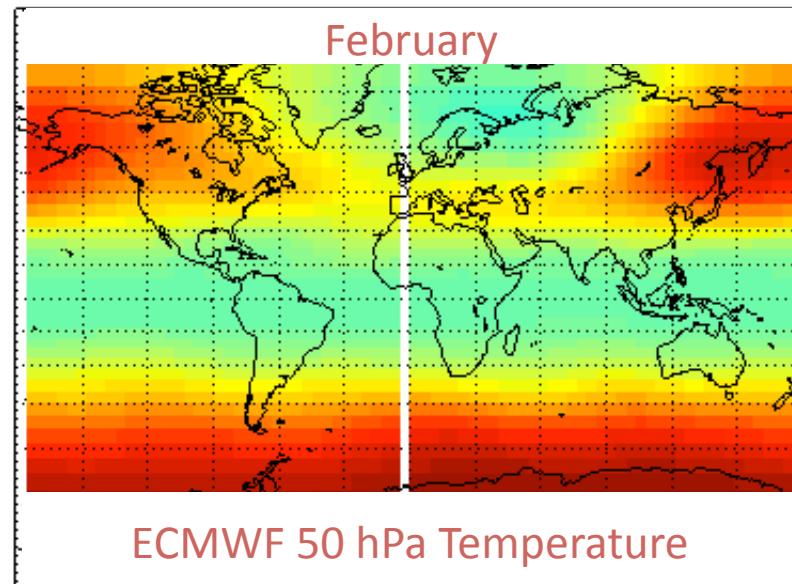


"CLARREO" Mean August Humidity 300hPa

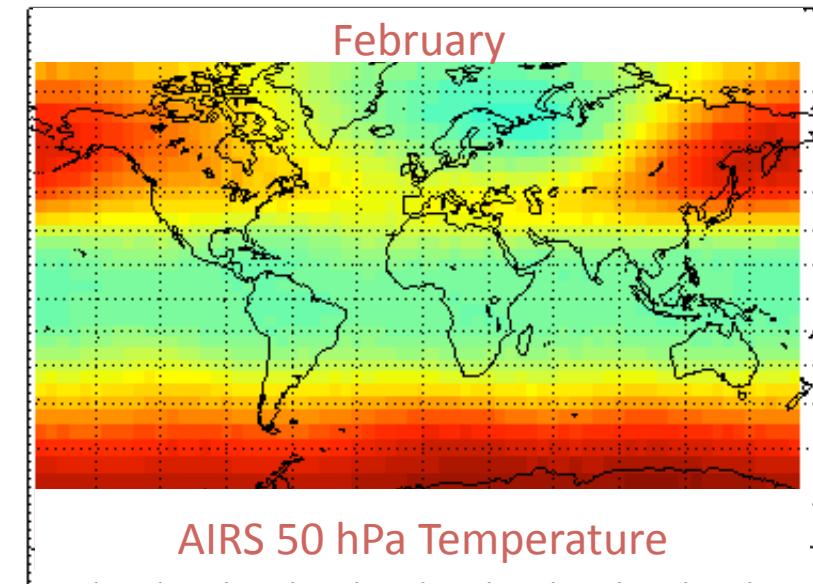


50 hPa Temperature (2003-2008)

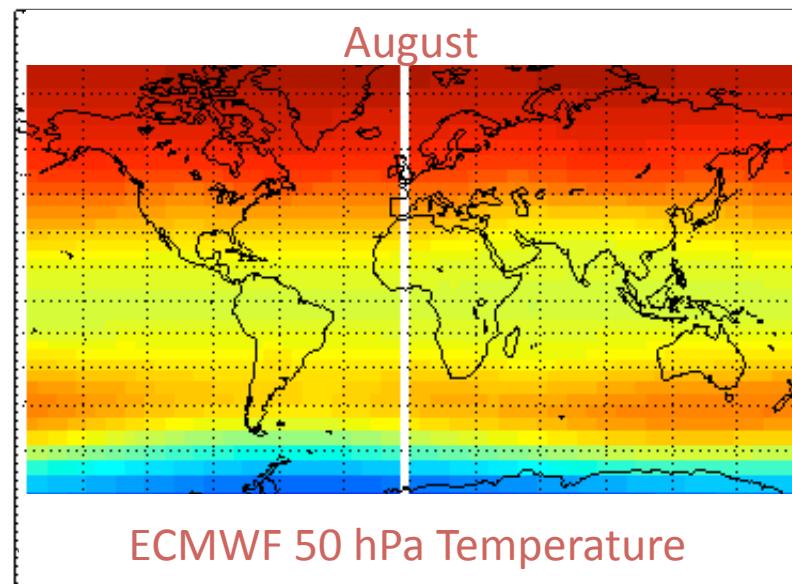
ECMWF Mean February 50 hPa Temperature



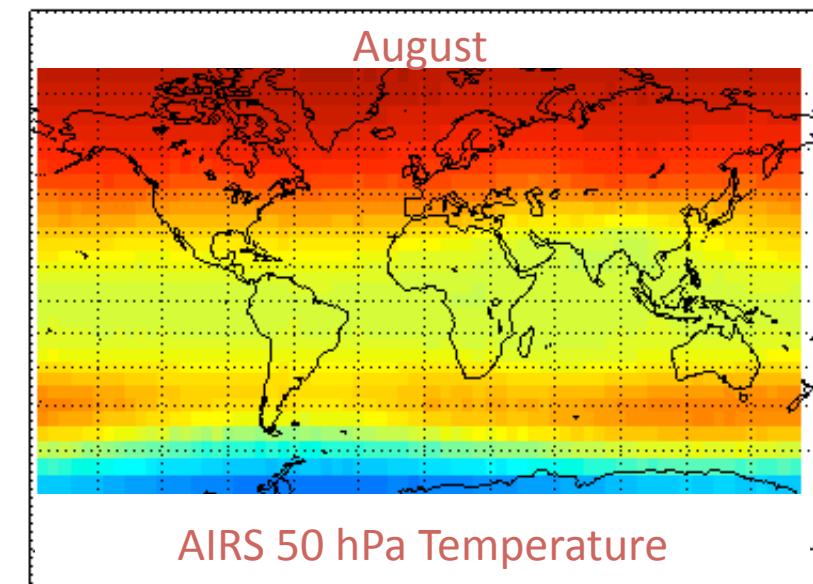
AIRS Mean February Temperature 52hPa



ECMWF Mean August 50 hPa Temperature

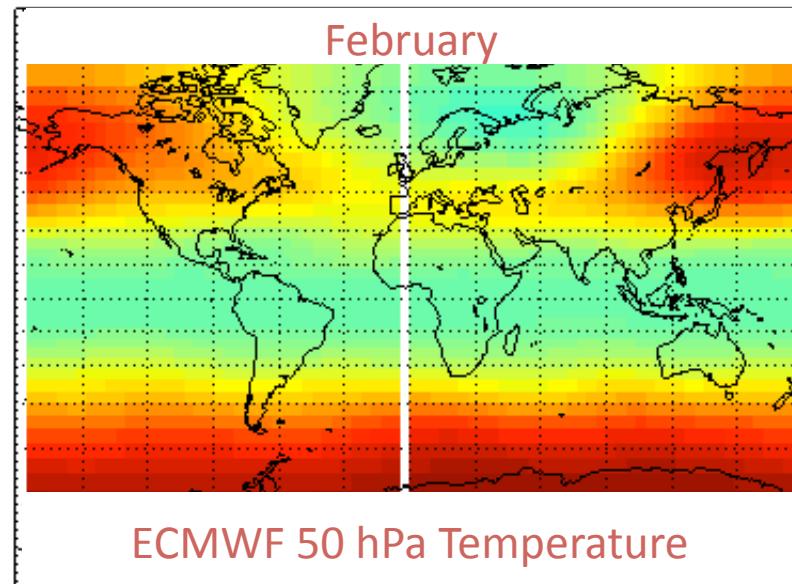


AIRS Mean August Temperature 52hPa

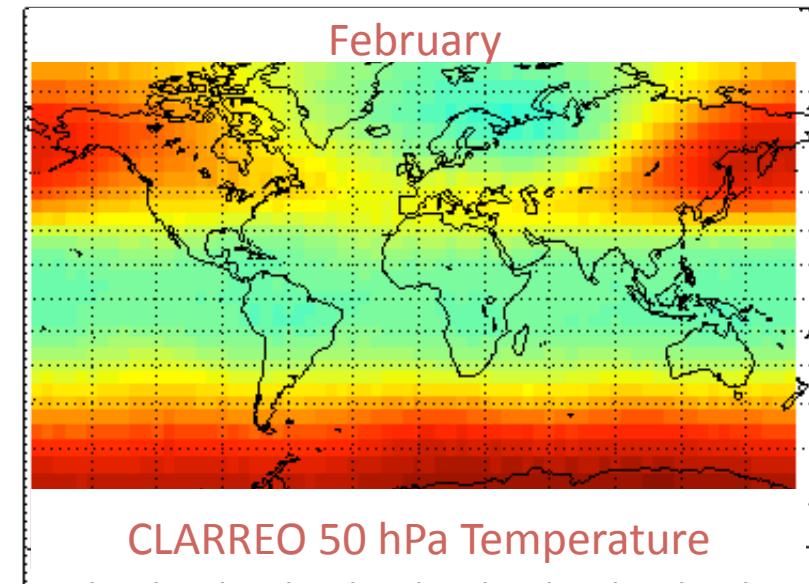


50 hPa Temperature (2003-2008)

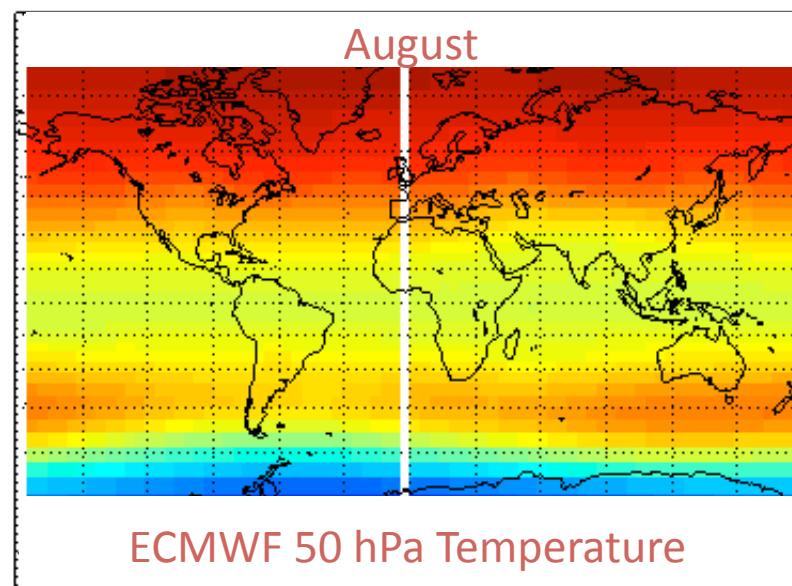
ECMWF Mean February 50 hPa Temperature



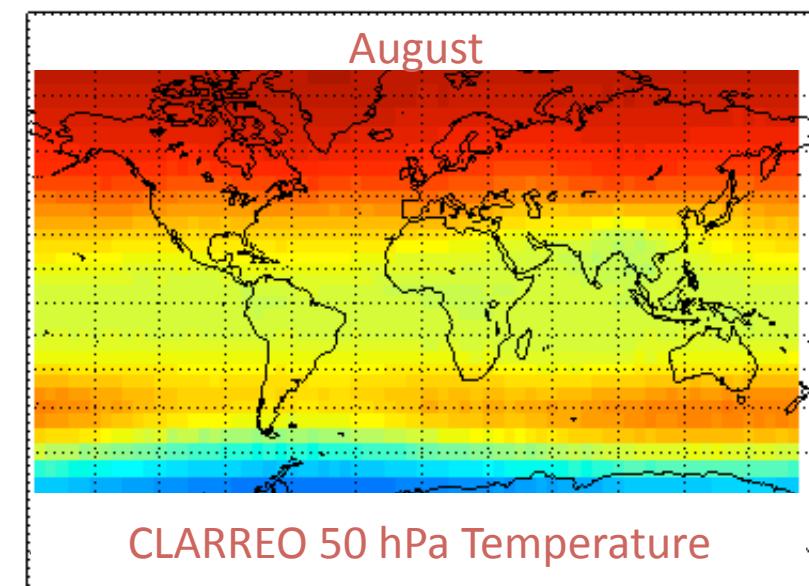
"CLARREO" Mean February Temperature 52hPa



ECMWF Mean August 50 hPa Temperature

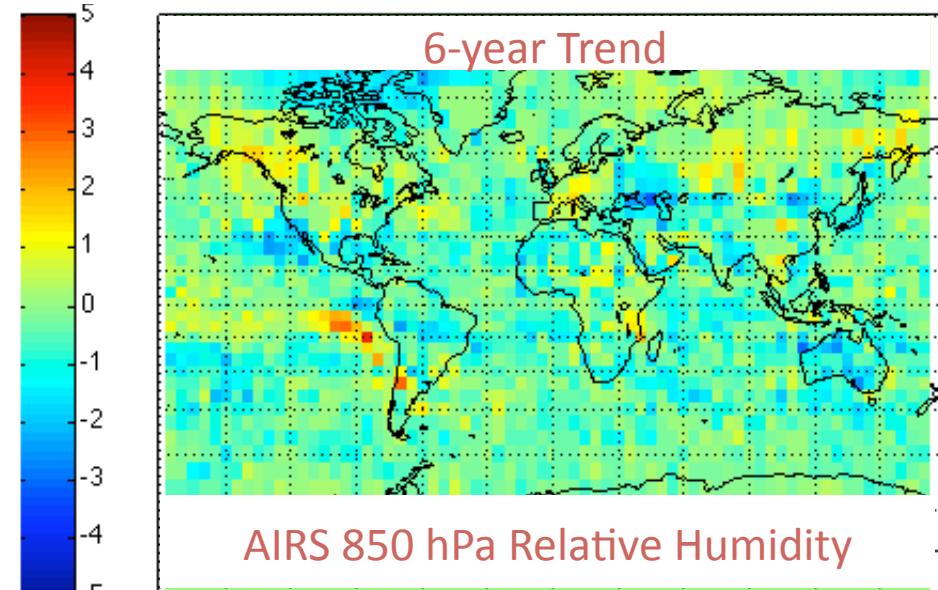
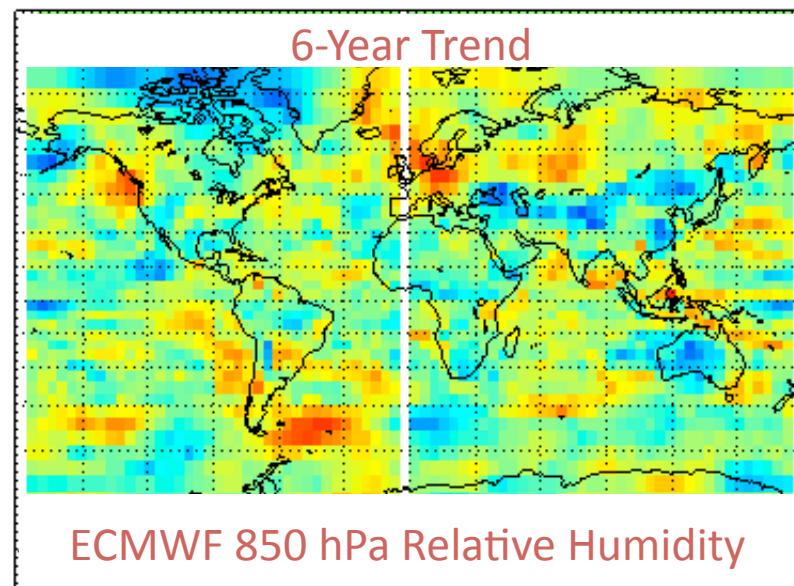
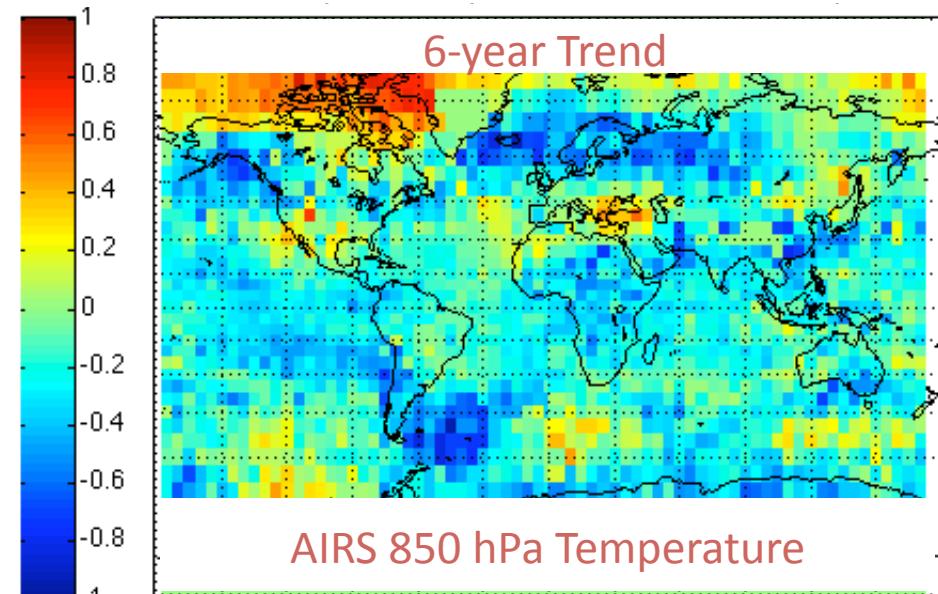
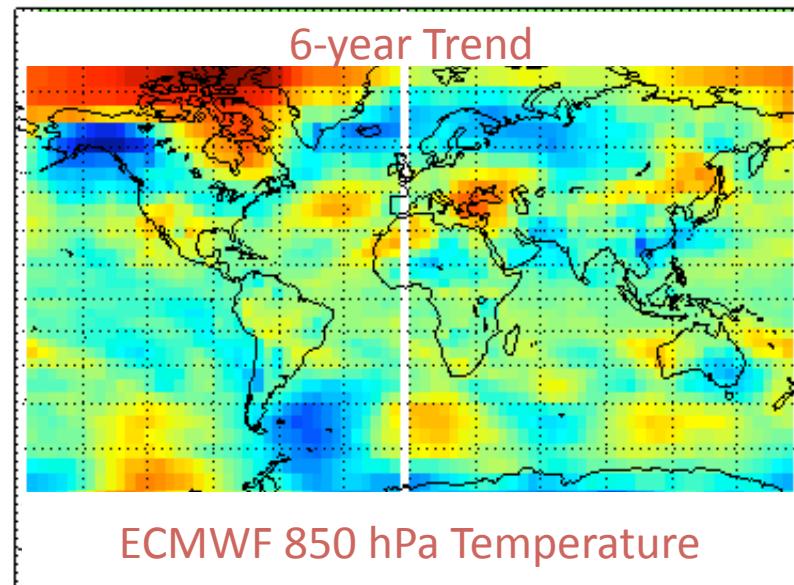


"CLARREO" Mean August Temperature 52hPa

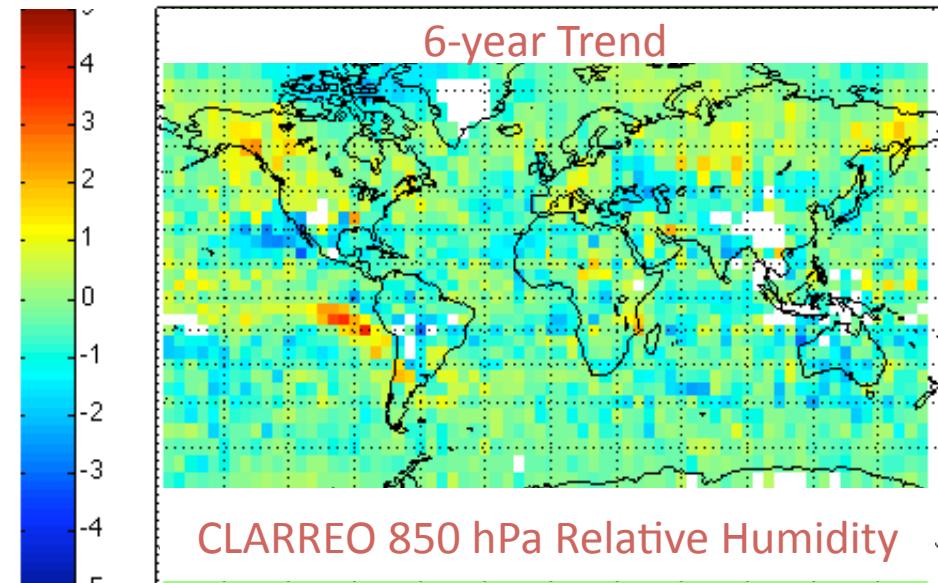
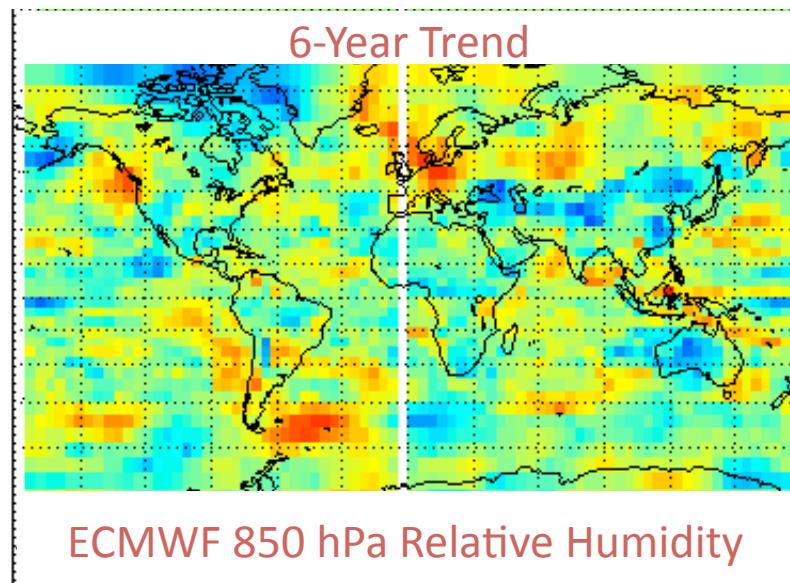
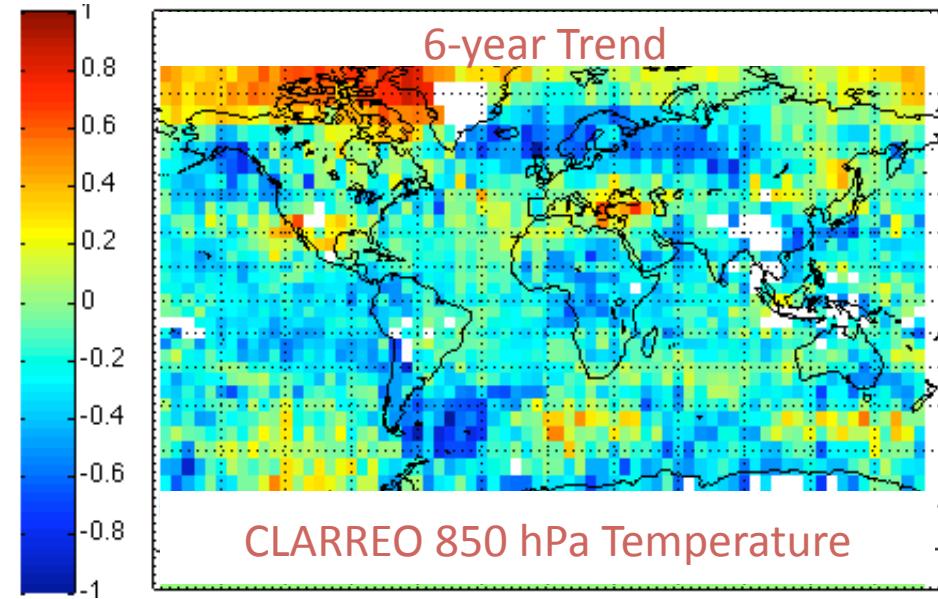
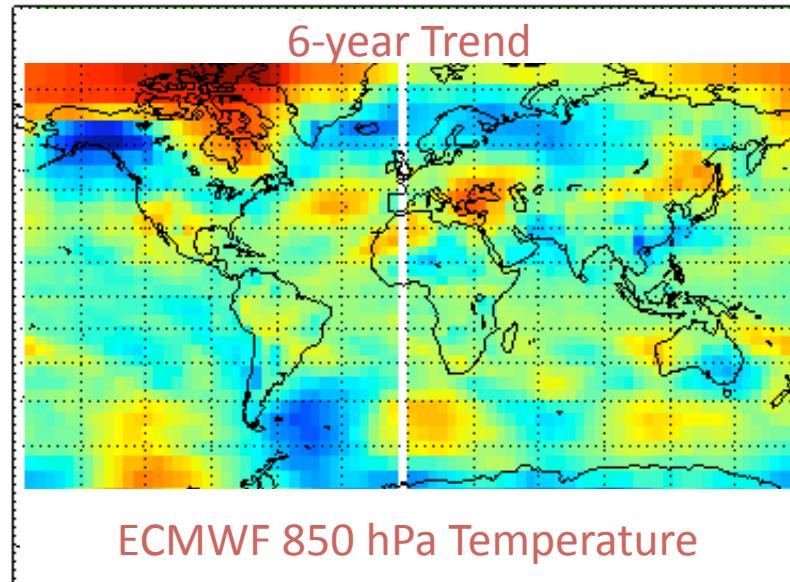


2003-2008
“Annual” (February + August)
Mean
Temperature
and
Relative Humidity
6-yr Trend
(Nadir AIRS/CLARREO Vs ECMWF)

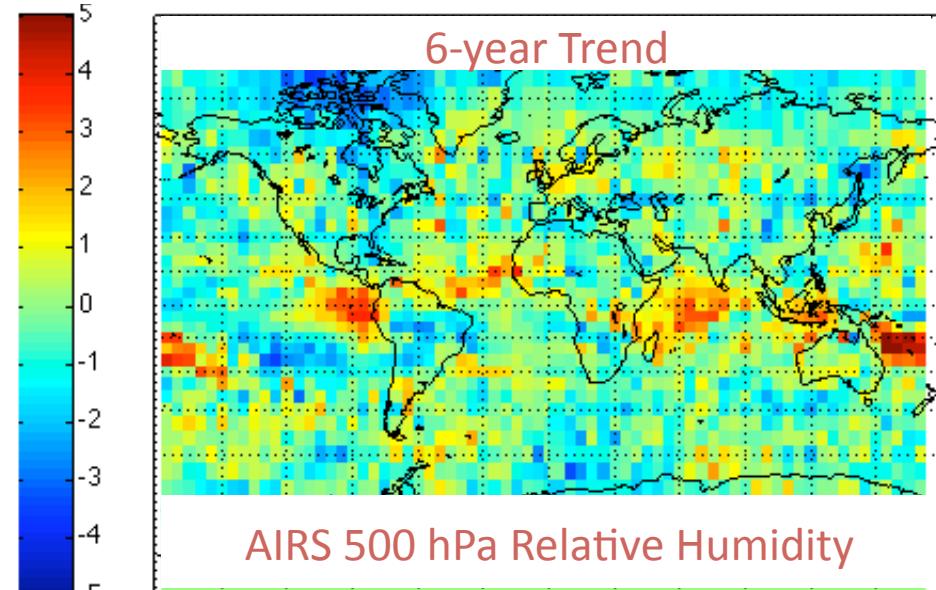
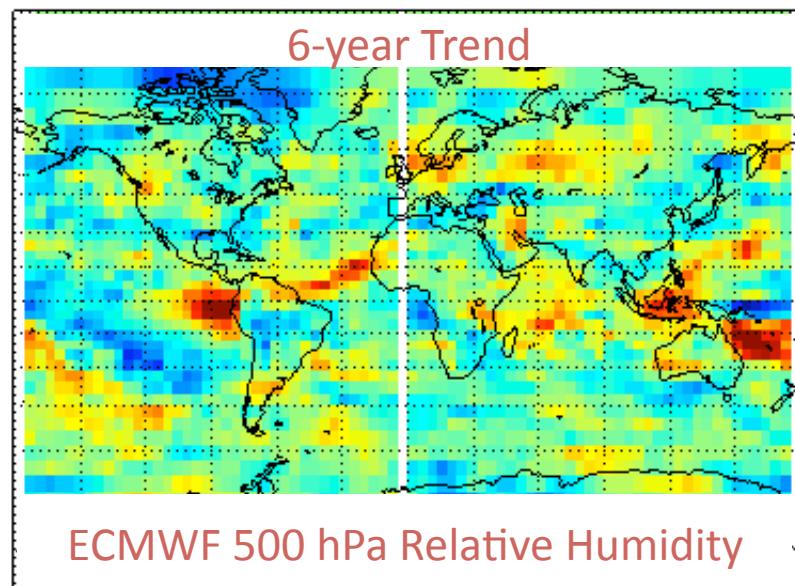
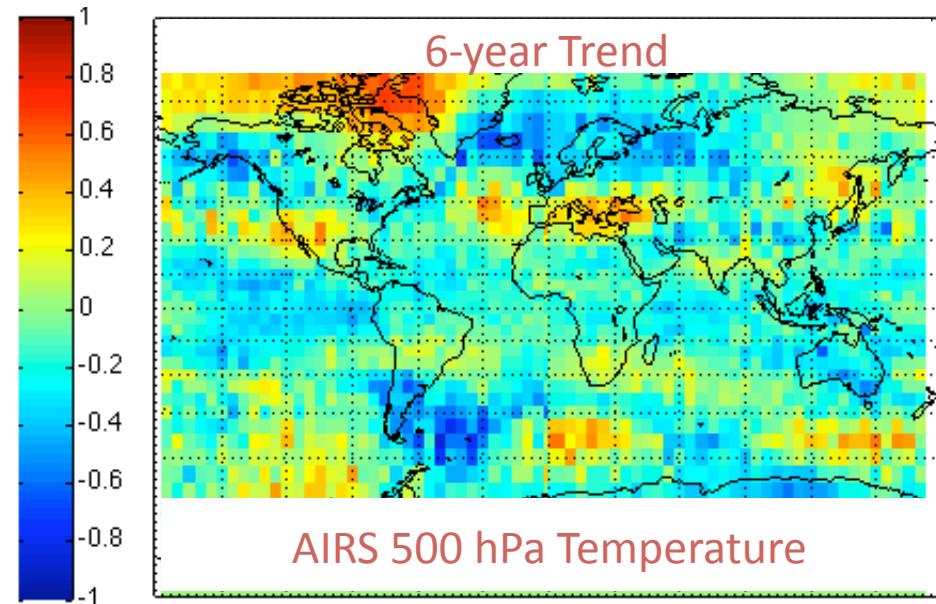
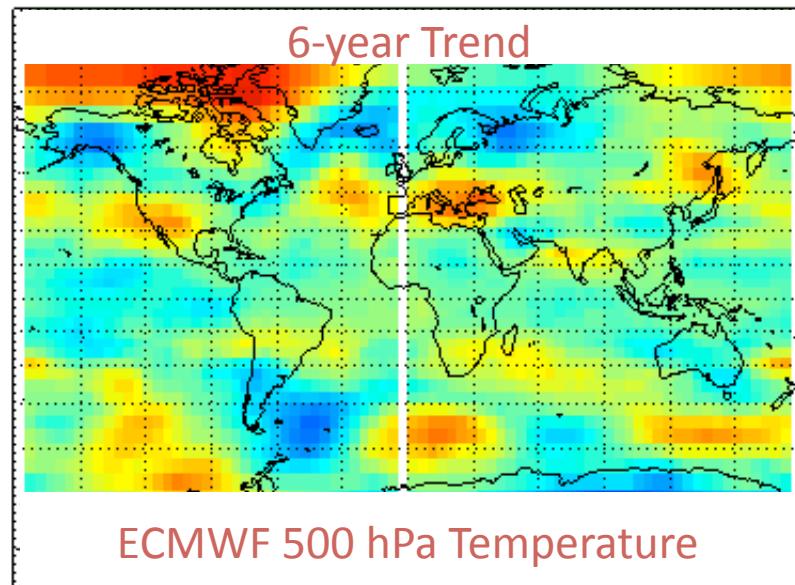
850 hPa 6-Year Trend (2003-2008)



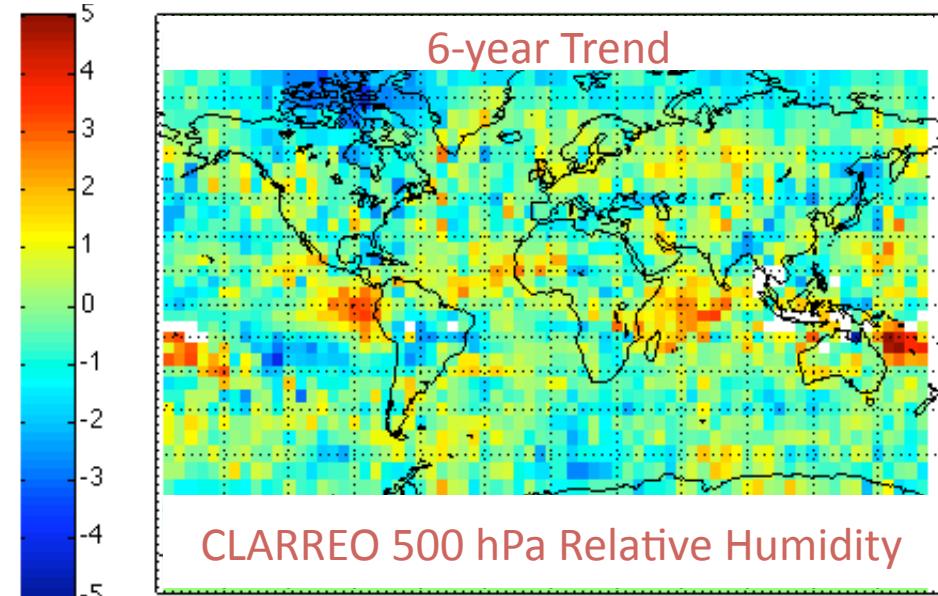
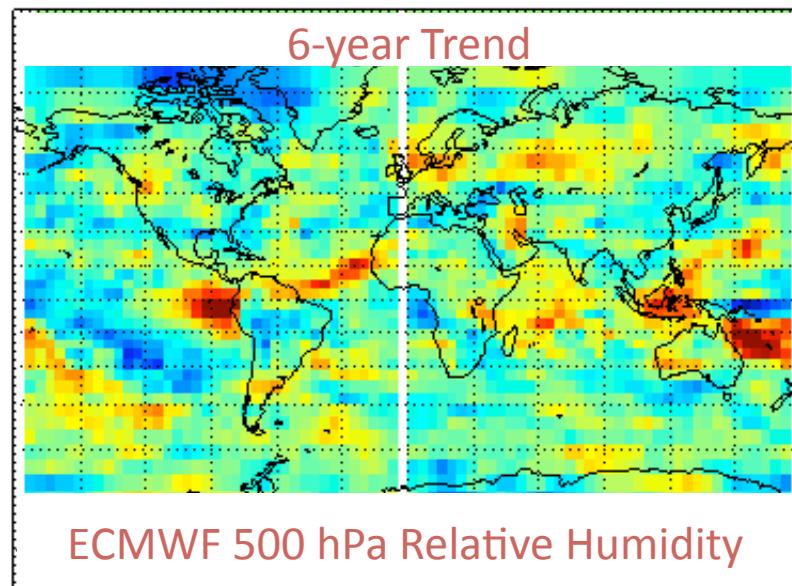
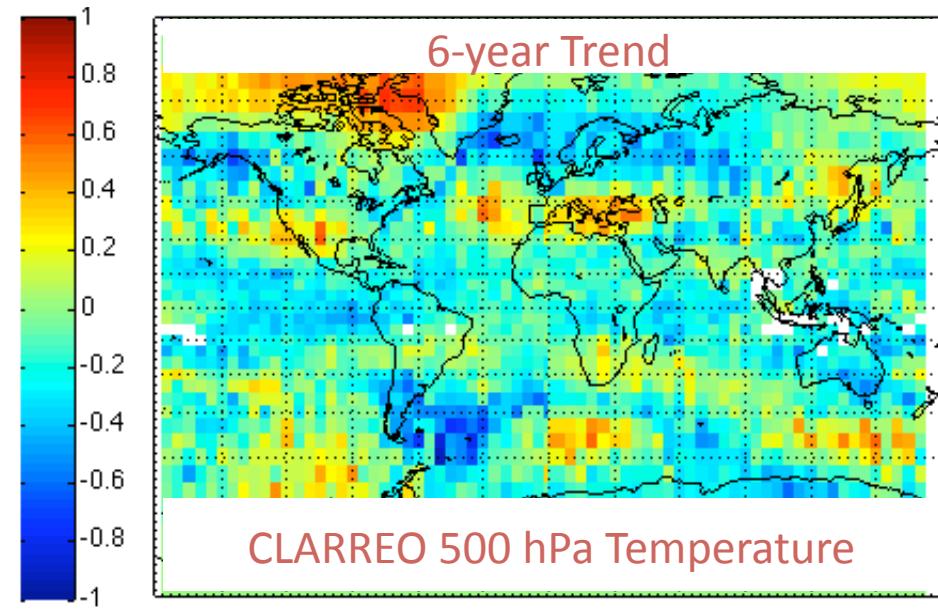
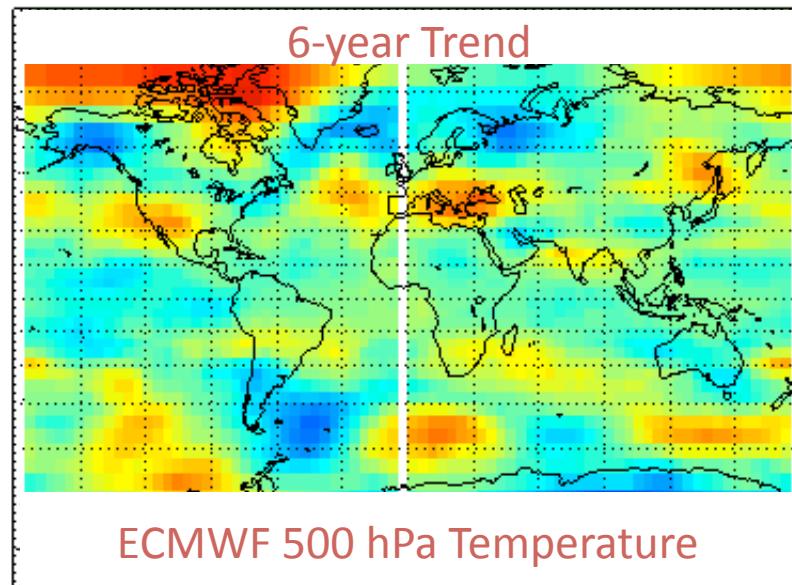
850 hPa 6-Year Trend (2003-2008)



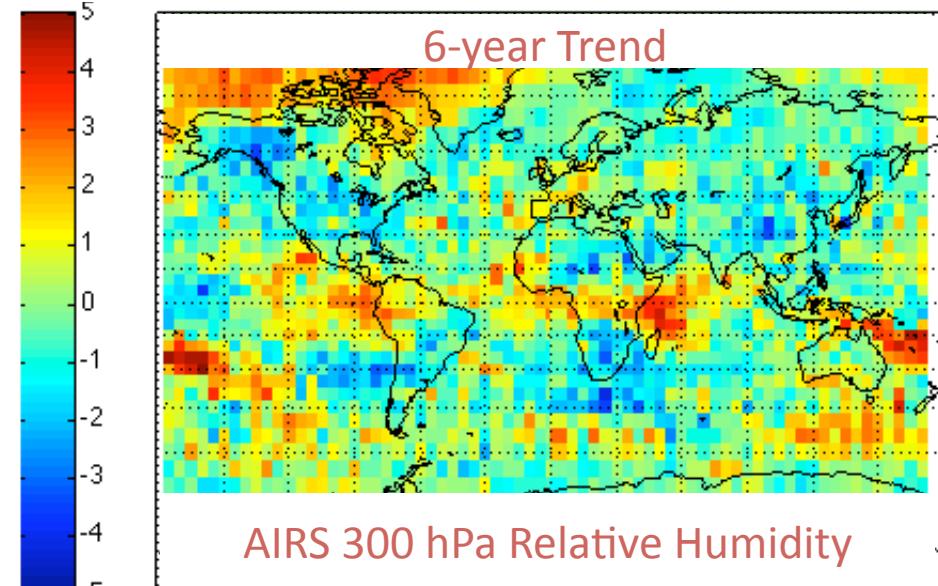
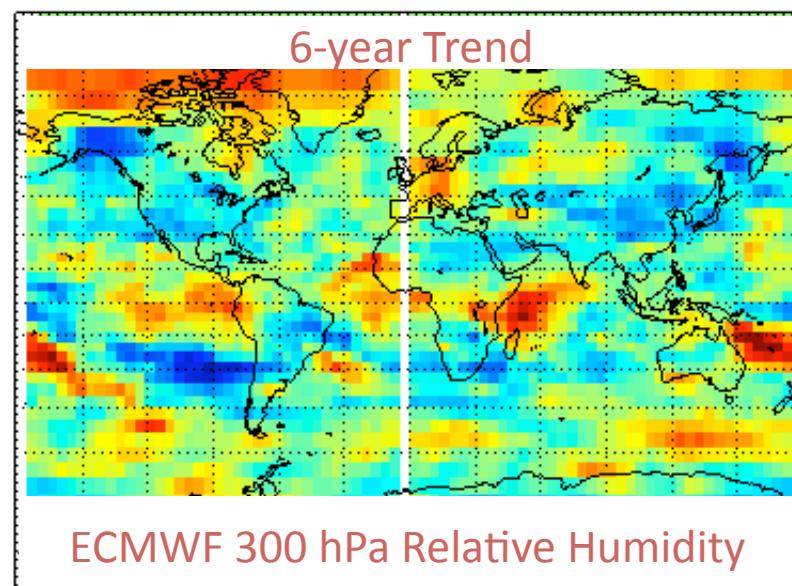
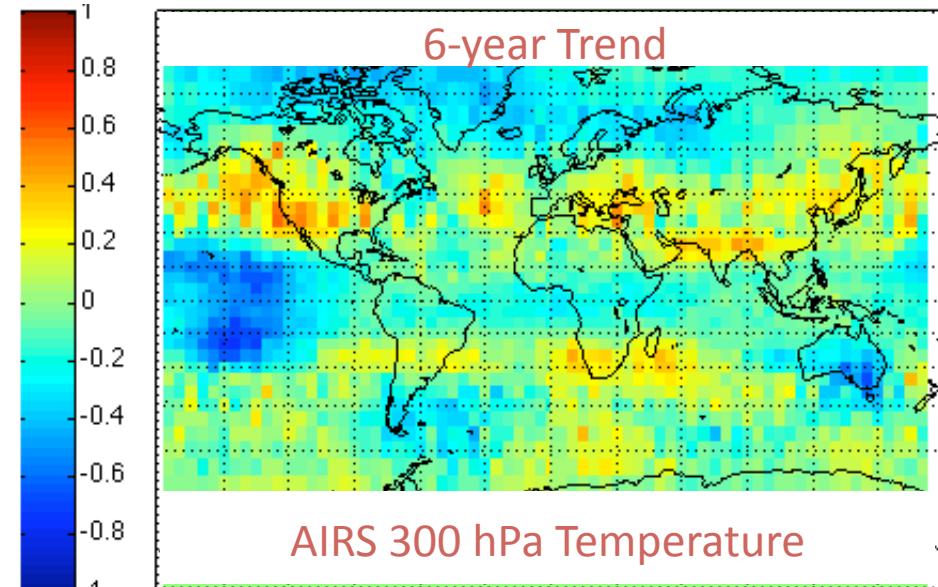
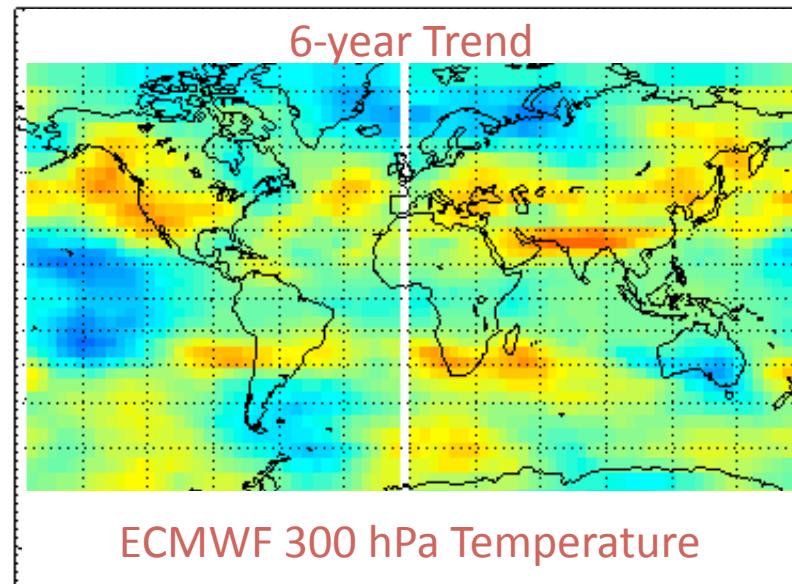
500 hPa 6-Year Trend (2003-2008)



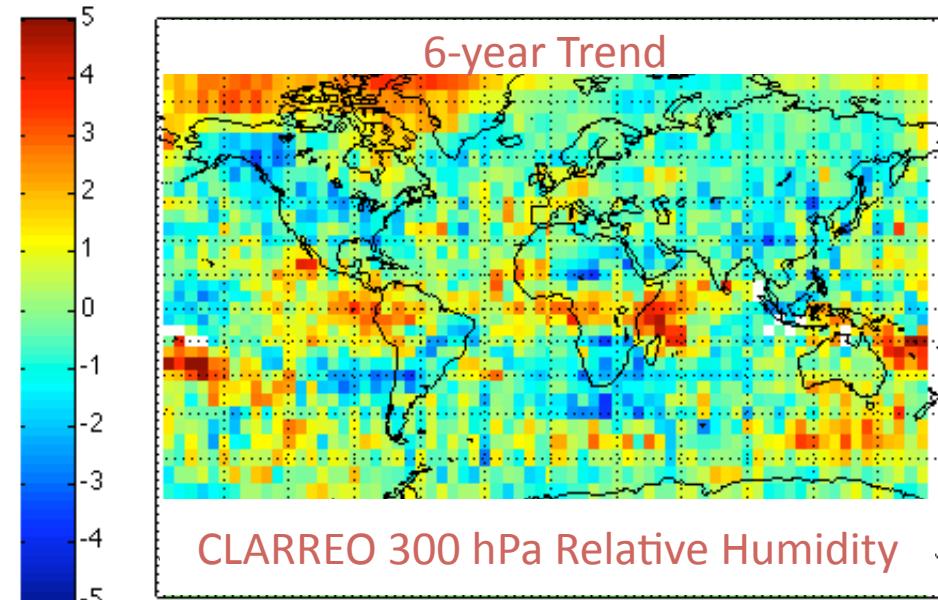
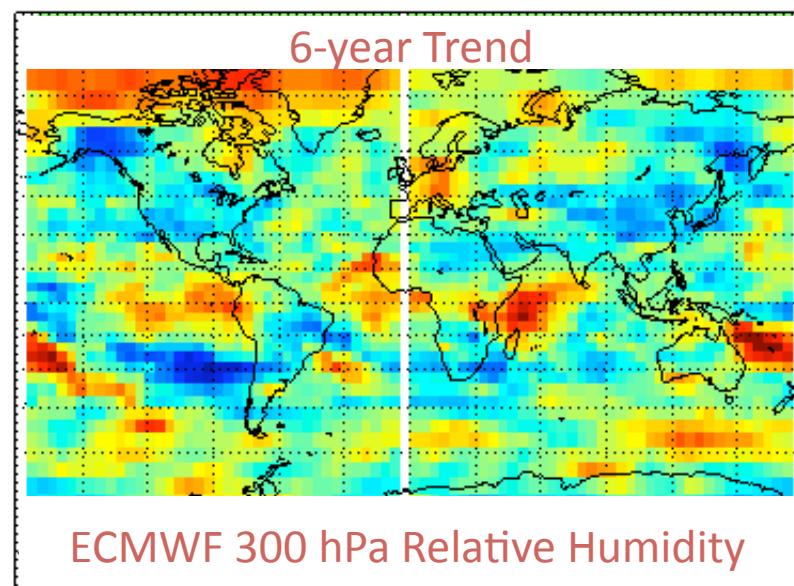
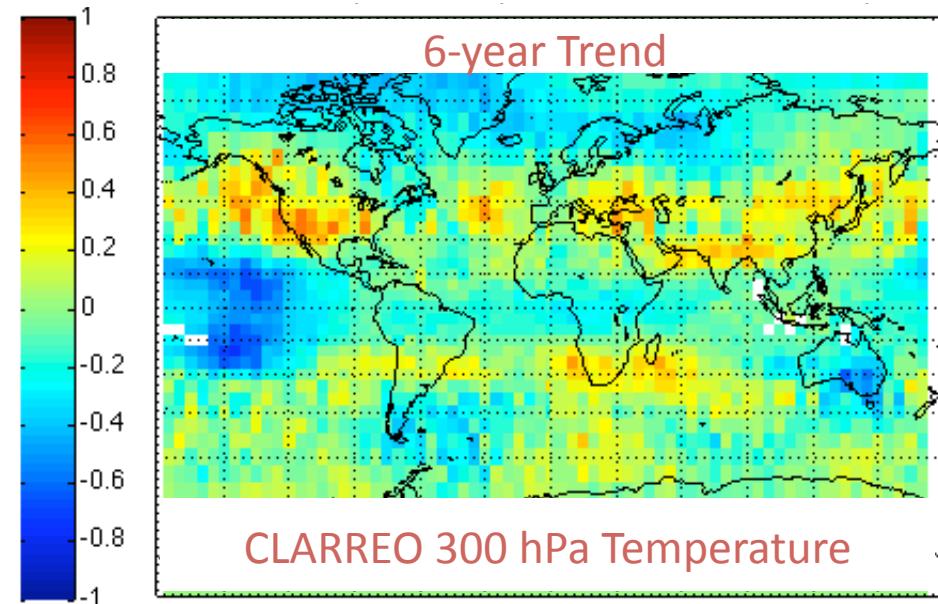
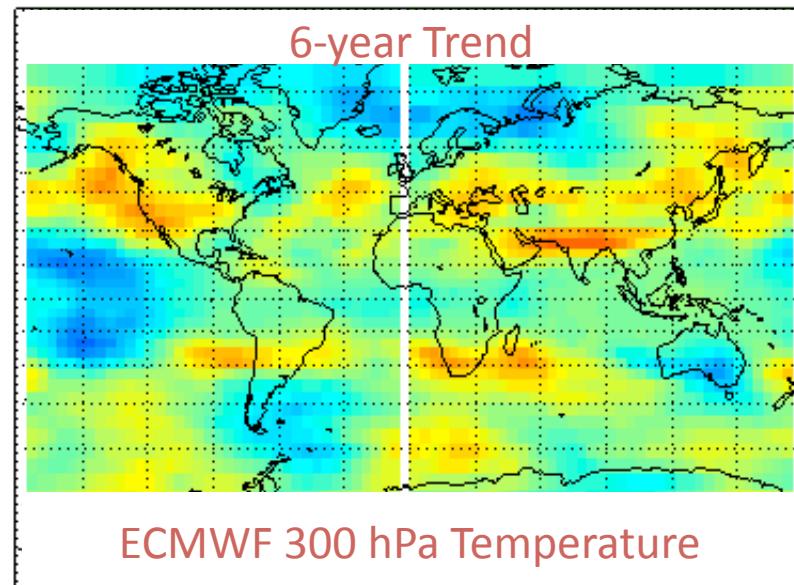
500 hPa 6-Year Trend (2003-2008)



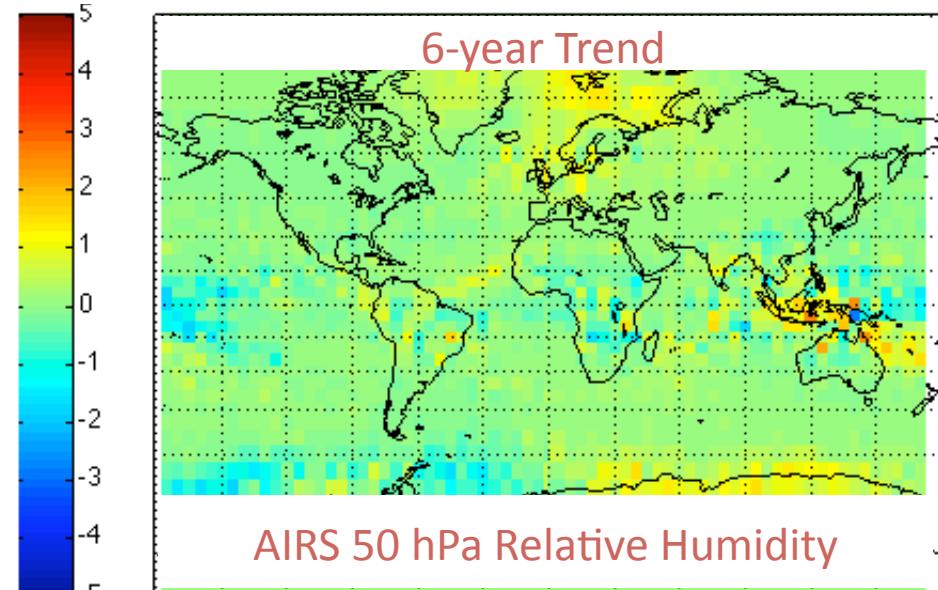
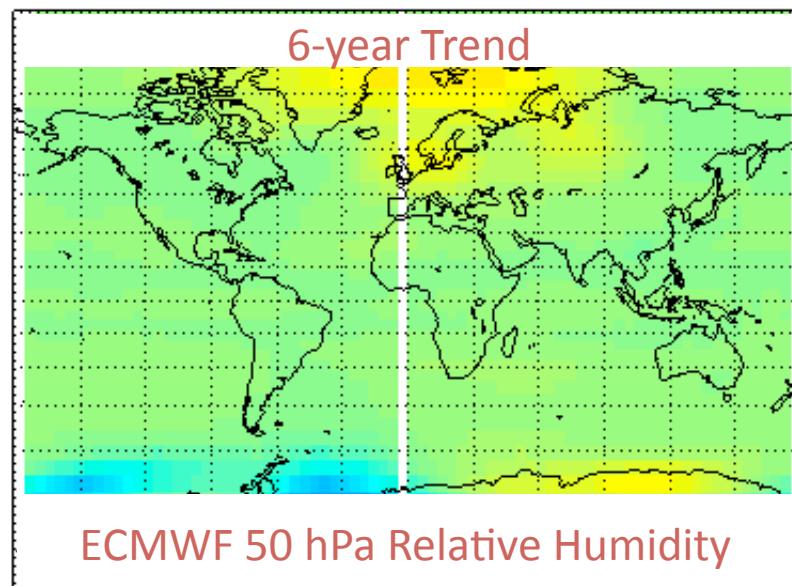
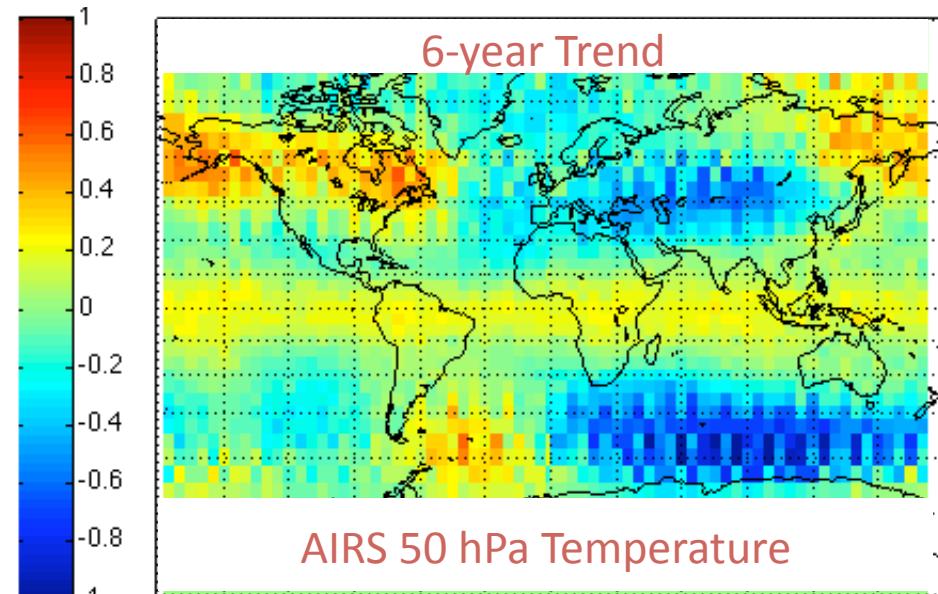
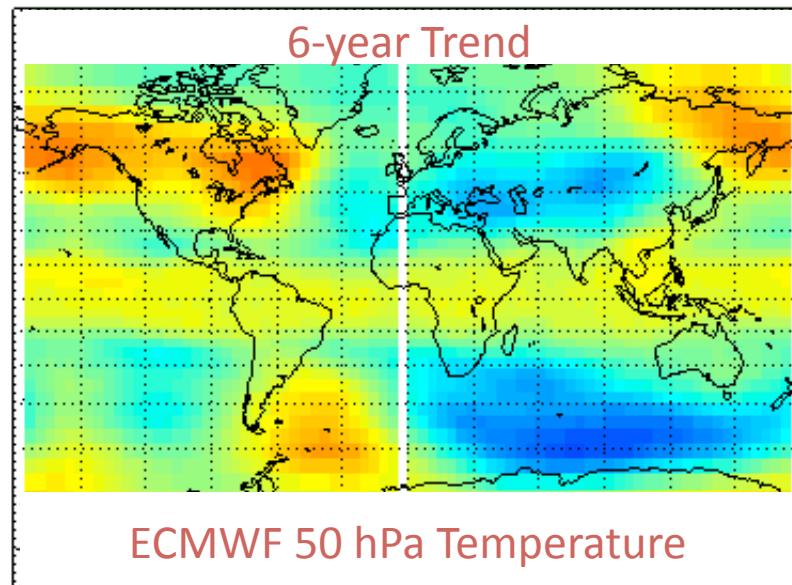
300 hPa 6-Year Trend (2003-2008)



300 hPa 6-Year Trend (2003-2008)

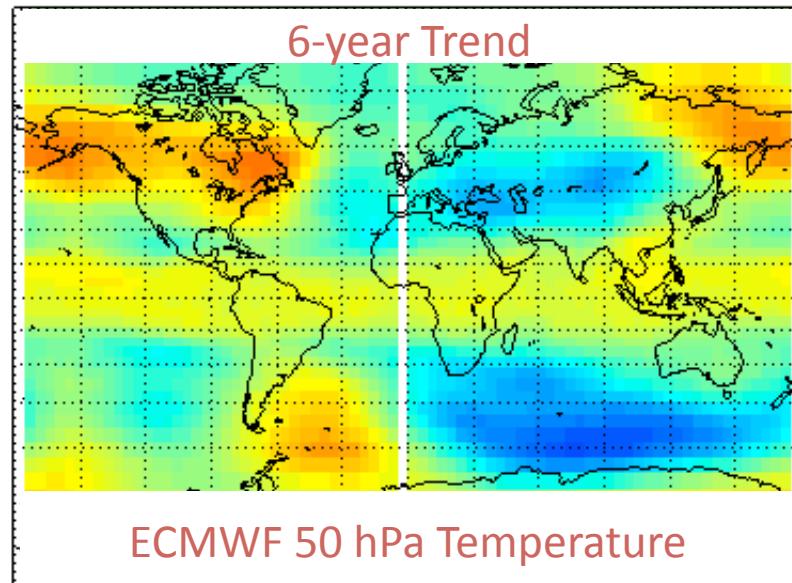


50 hPa 6-Year Trend (2003-2008)

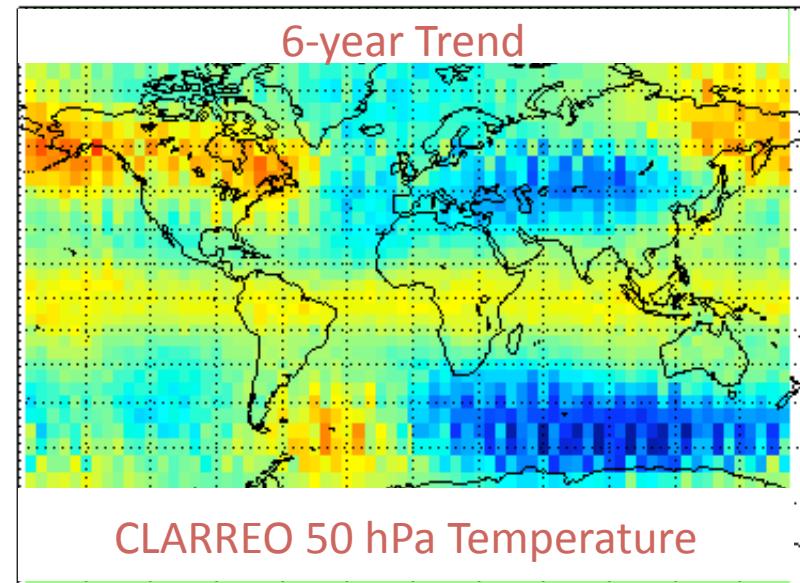


50 hPa 6-Year Trend (2003-2008)

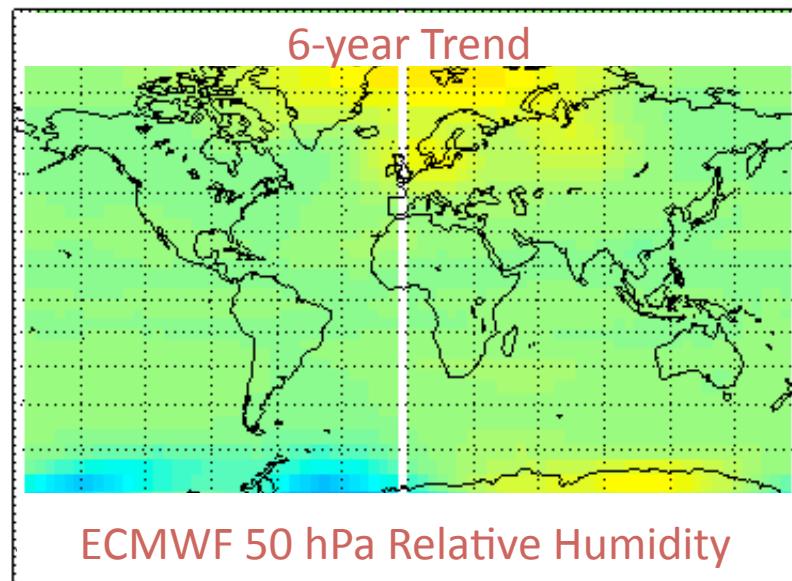
ECMWF 6-yr Trend 50 hPa Temperature 0.01264K / year



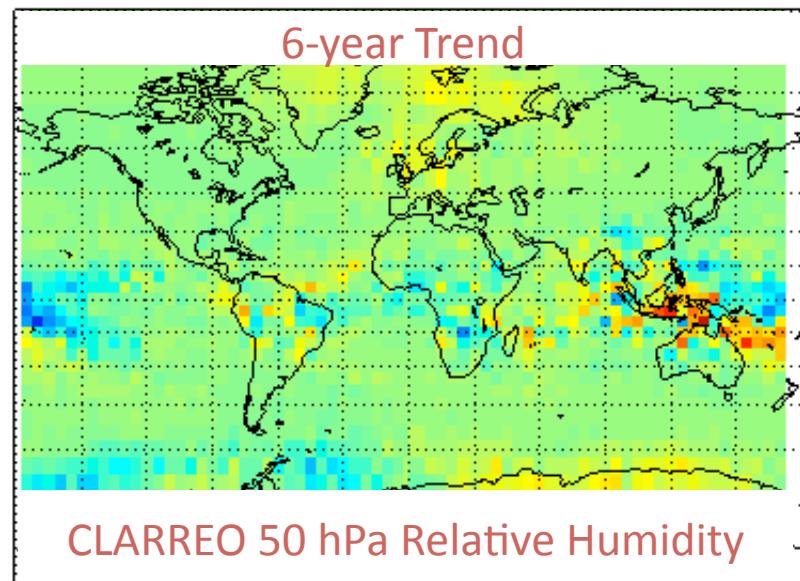
CLARREO 6-yr trend Temperature 52hPa -0.025934 K / yr



ECMWF 6-yr Trend 50 hPa Relative Humidity 0.03216% / year



"CLARREO" 6-yr Trend Humidity 52hPa 0.02777 % / yr



Global Mean Trends (ECMWF Vs AIRS Vs CLARREO)

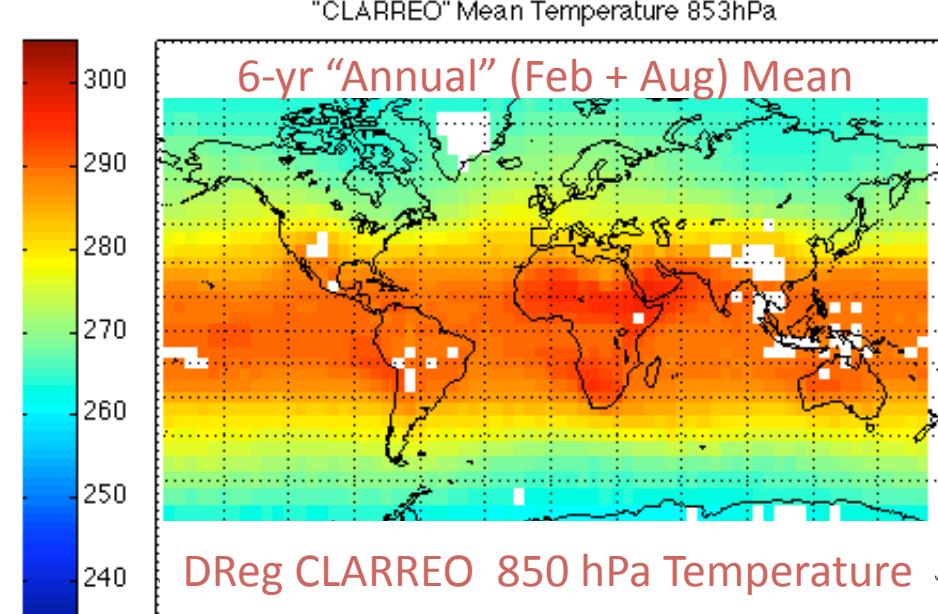
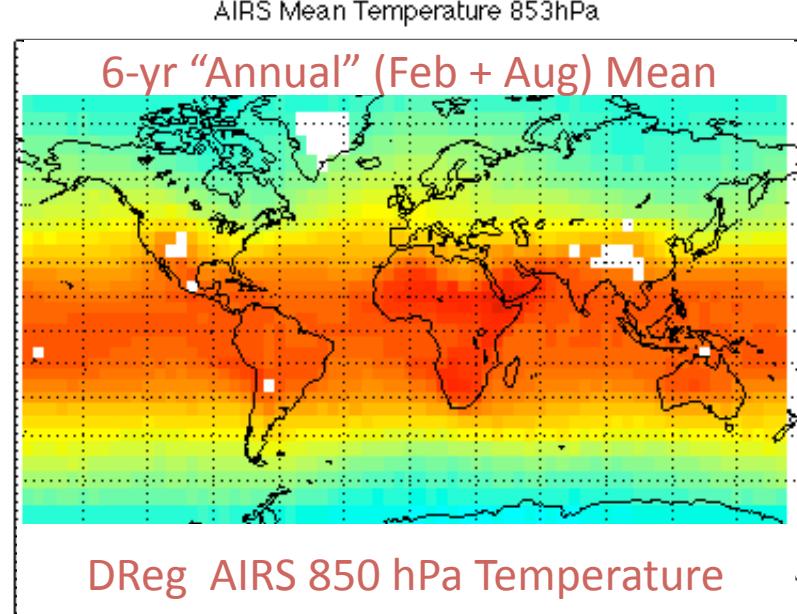
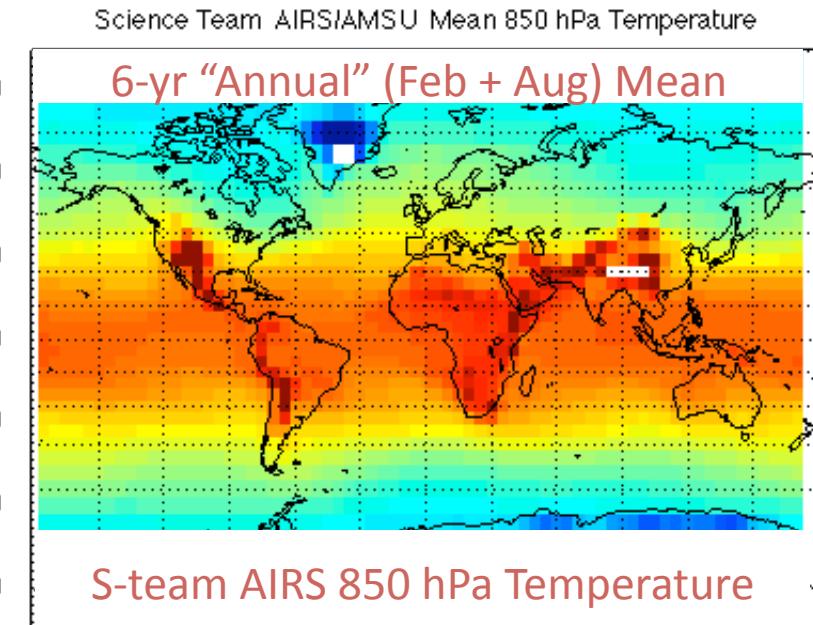
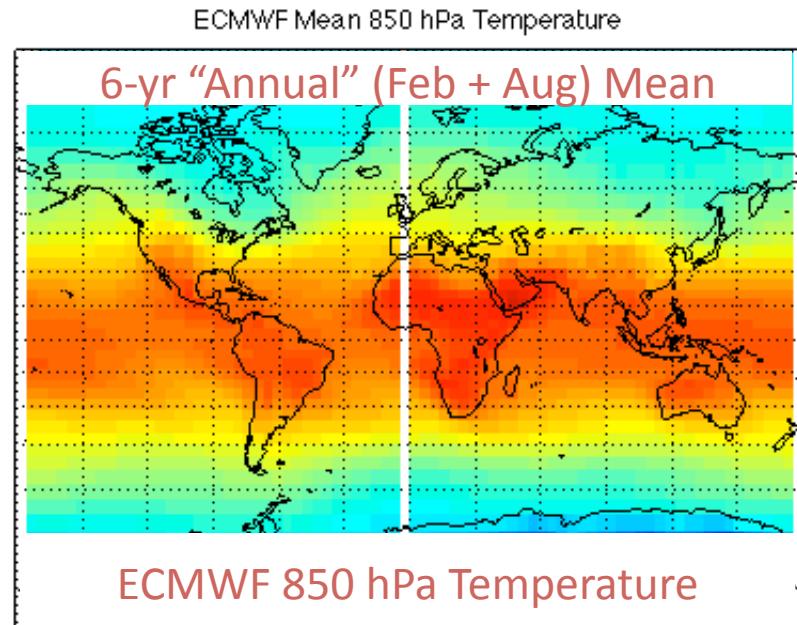
Parameter	ECMWF	AIRS	CLARREO	Difference
850 T (K/yr)	-0.029	-0.120	-0.198	-0.078
850 RH (%/ yr)	+0.154	-0.366	-0.361	+0.005
500 T	-0.021	-0.123	-0.125	-0.002
500 RH	+0.073	-0.078	-0.106	-0.028
300 T	-0.006	-0.070	-0.066	+0.006
300 RH	-0.093	+0.071	+0.052	-0.019
50 T	+0.013	-0.027	-0.026	-0.001

Summary & Conclusion

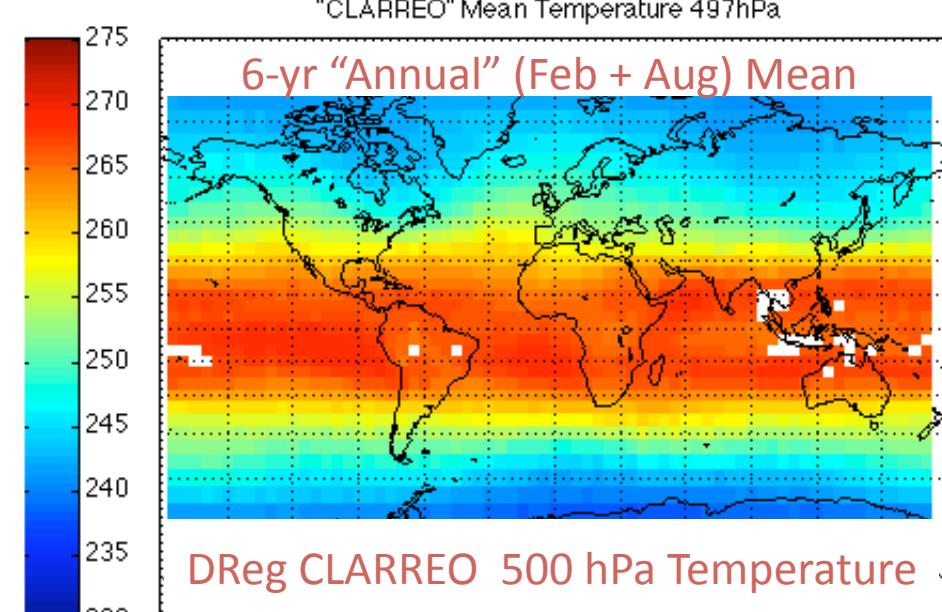
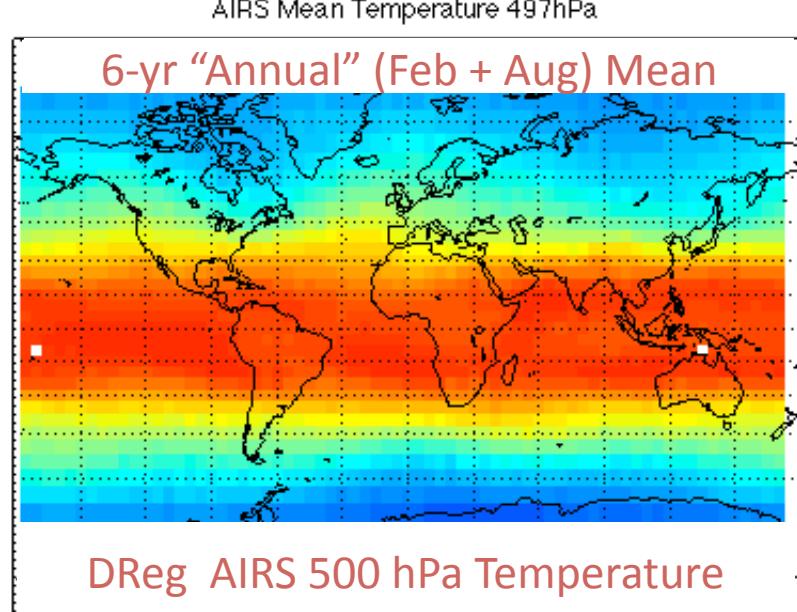
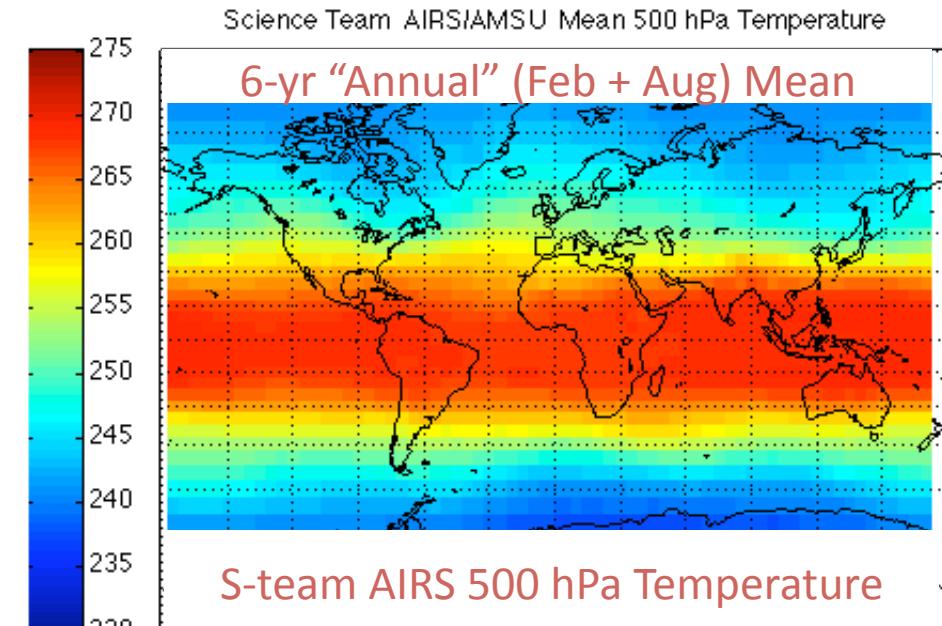
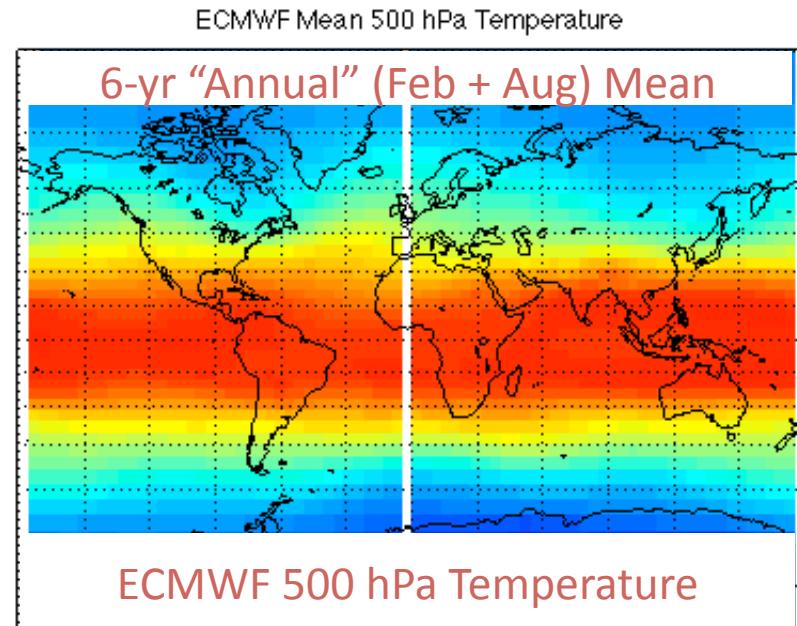
- ECMWF ERA must be very good. Compares well with independent satellite product (i.e., Dual EOF Regn AIRS)
- Dual EOF Regression Single FOV Retrieval works well - 100-km FOV compares well to 13-km FOV
- Amazing correspondence between monthly mean values of twice per day Nadir AIRS and CLARREO proxy retrievals with ECMWF analyses of all GOS data
 - Regional *Monthly Means*
 - Regional 6-year *trends* in “Annual” Mean
- Next step: Produce 5-Decade regional trend results from 1970 IRIS hyperspectral FTS data and AIRS/IASI data degraded to IRIS spectral (1.4 cm^{-1} , unapodized) and spatial (100-km) resolution.

2003-2006
Comparisons of Results
with AIRS Science Team
Temperature
and
Relative Humidity

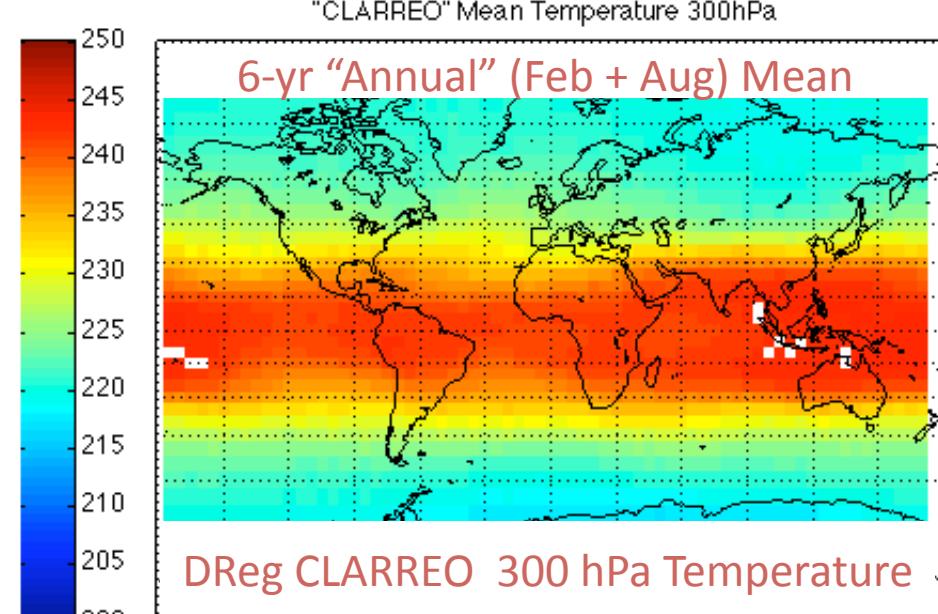
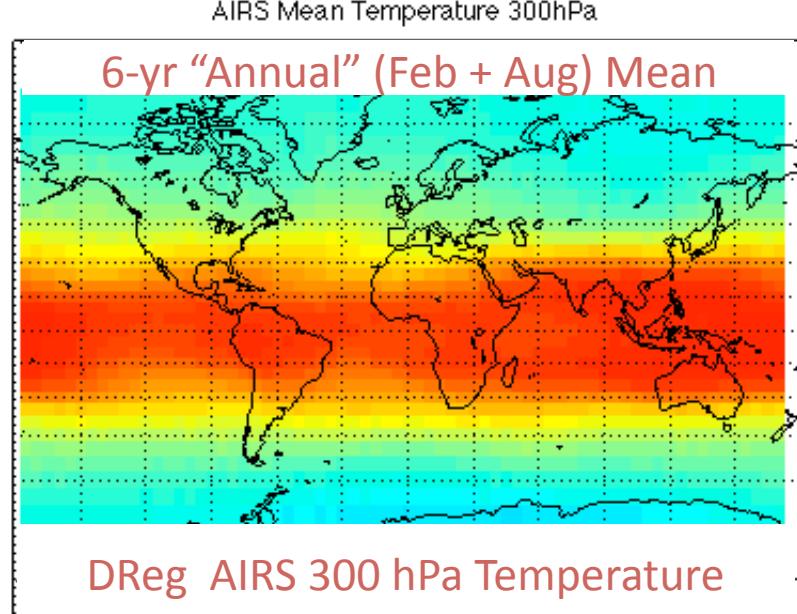
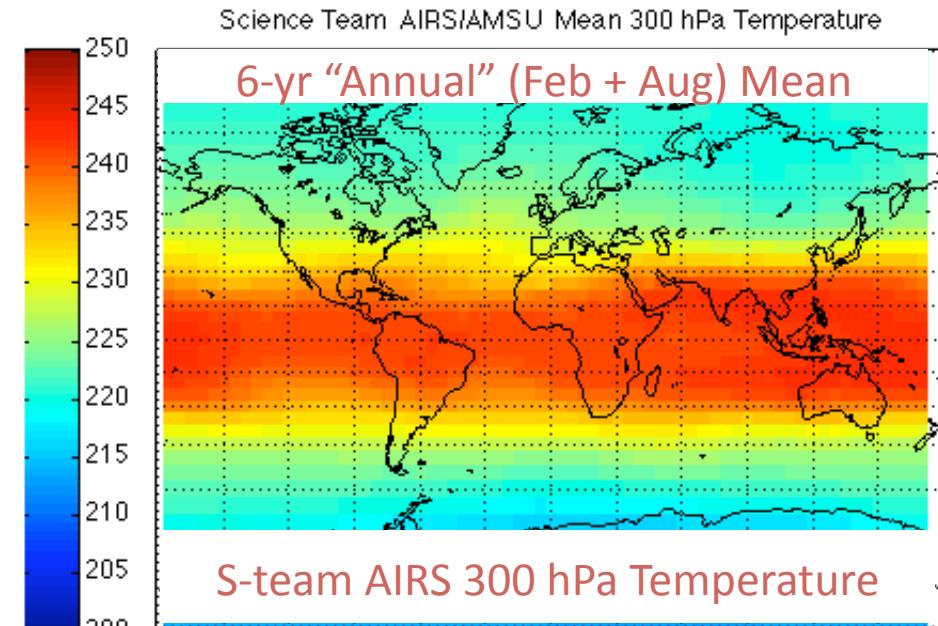
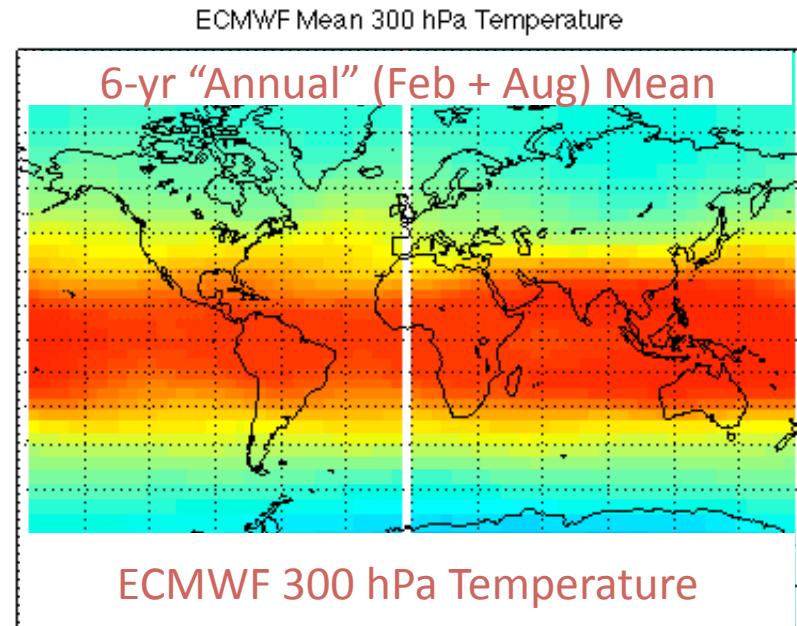
Dual Regn AIRS/CLARREO, ScTm AIRS+AMSU, ECMWF (2003-2008)



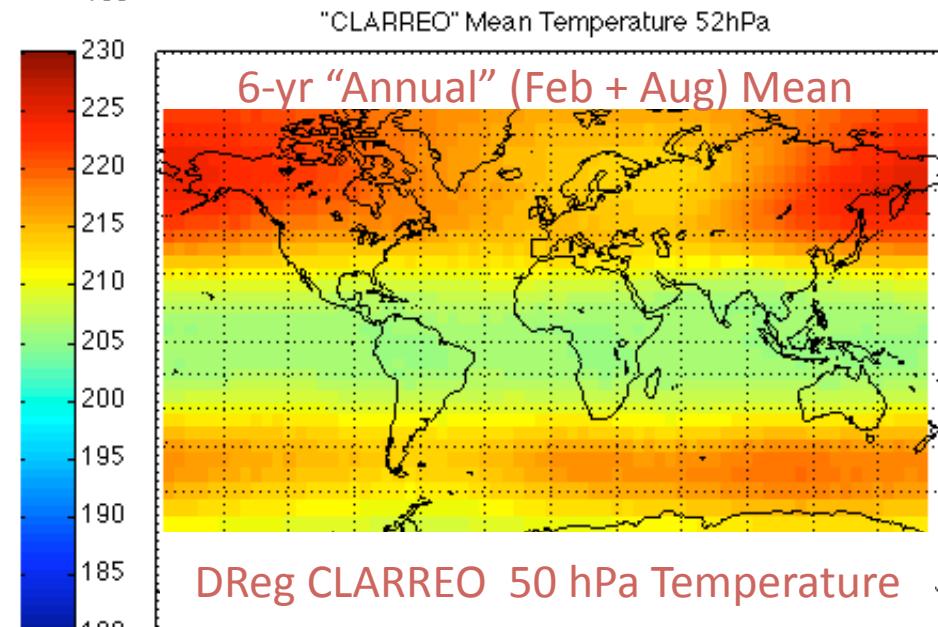
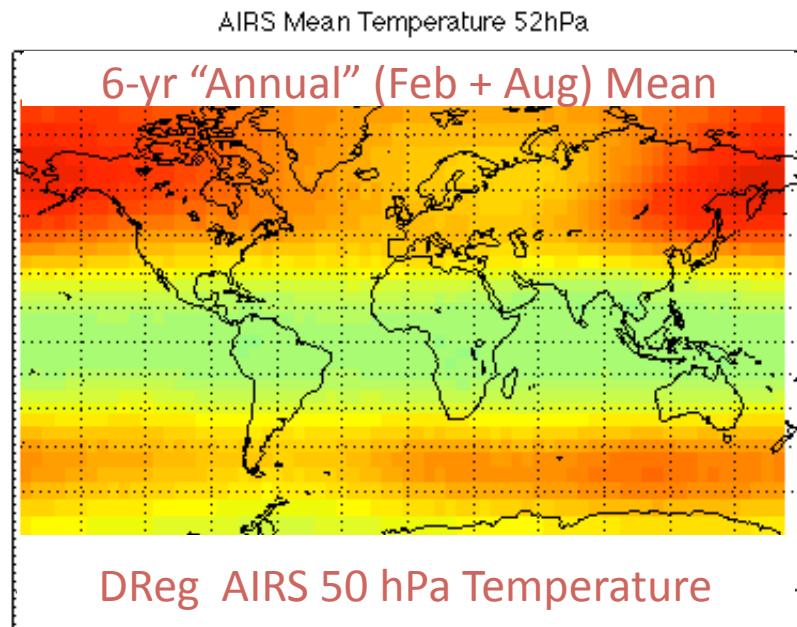
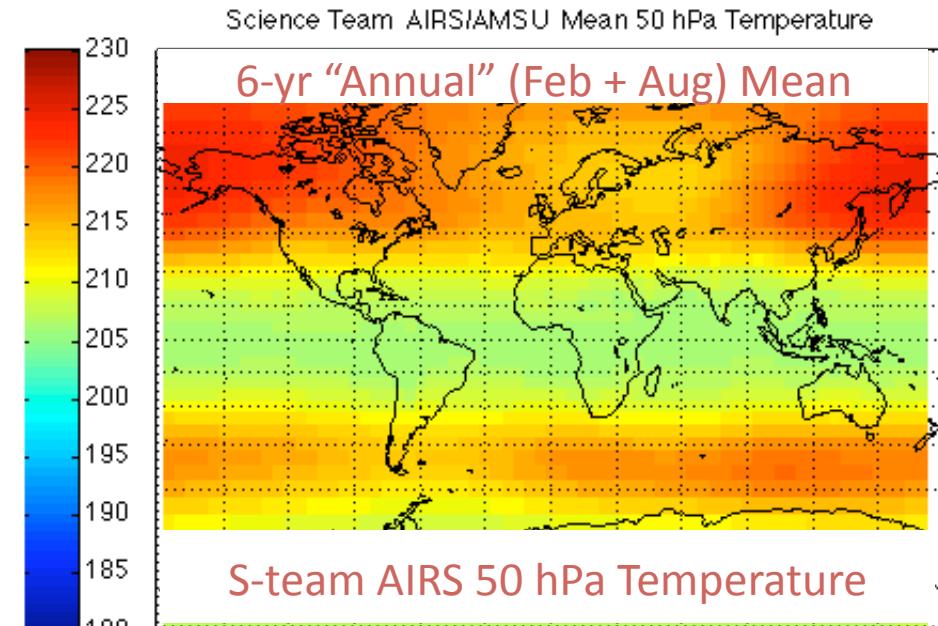
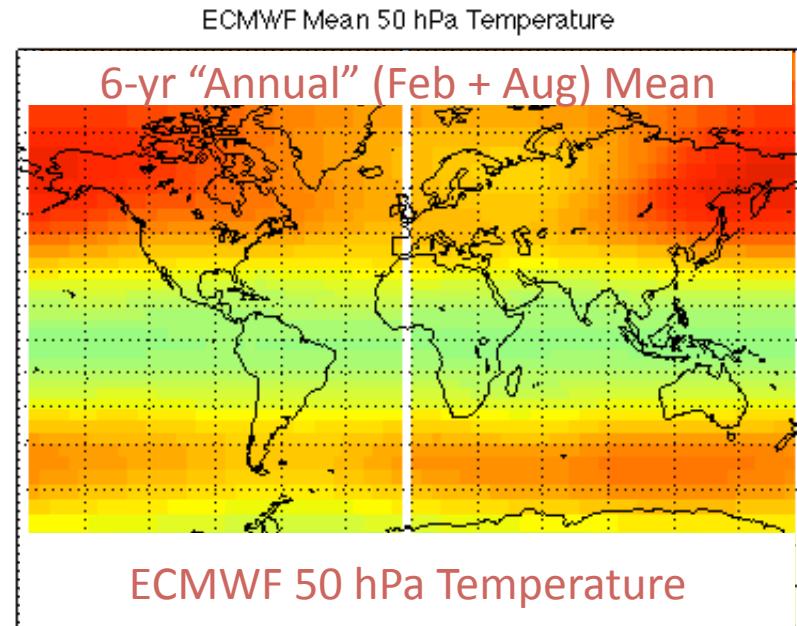
Dual Regn AIRS/CLARREO, ScTm AIRS+AMSU, ECMWF (2003-2008)



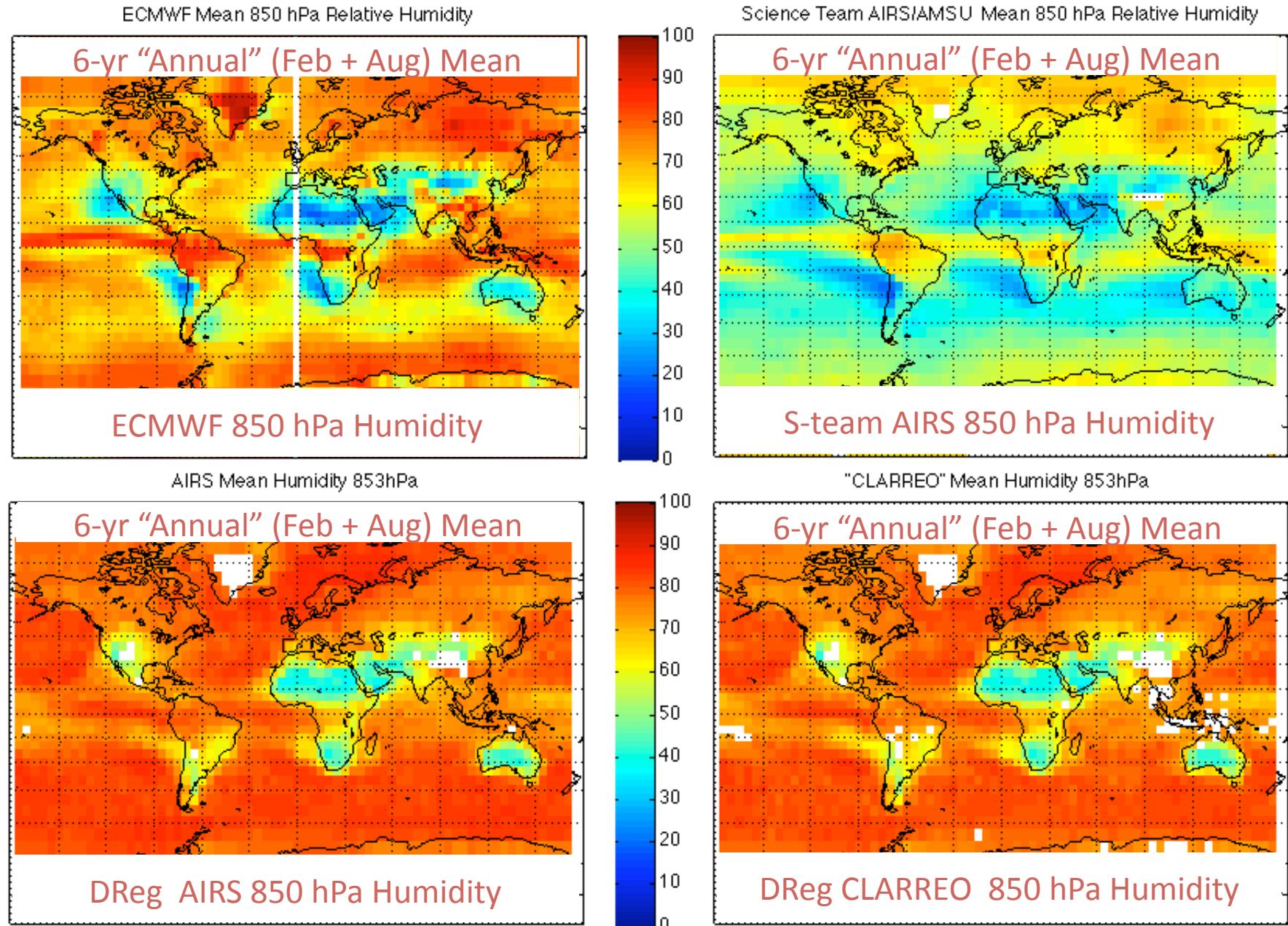
Dual Regn AIRS/CLARREO, ScTm AIRS+AMSU, ECMWF (2003-2008)



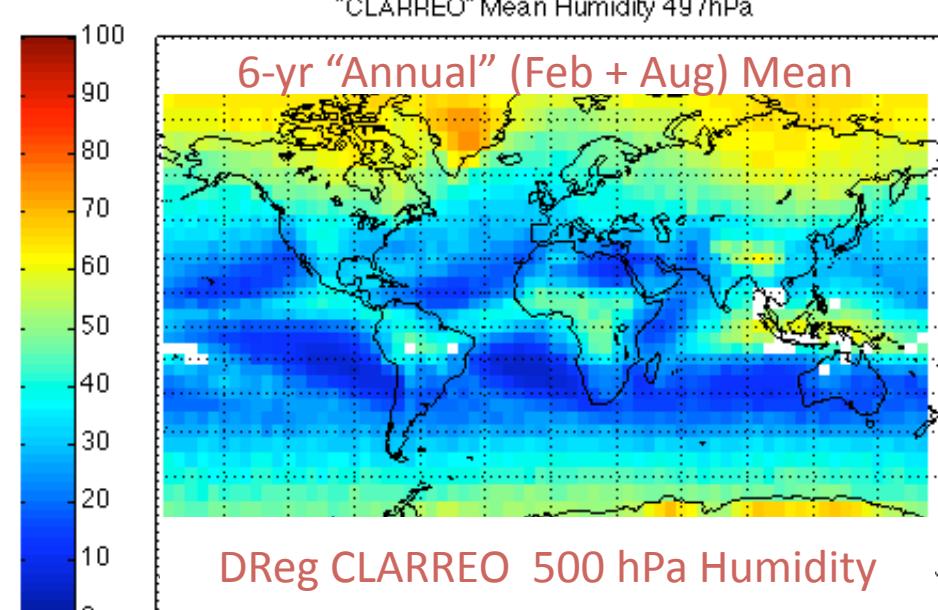
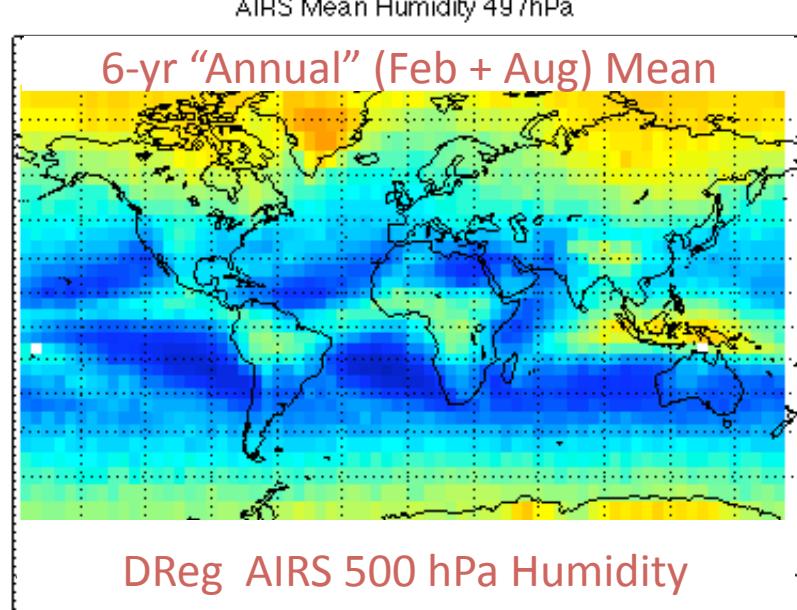
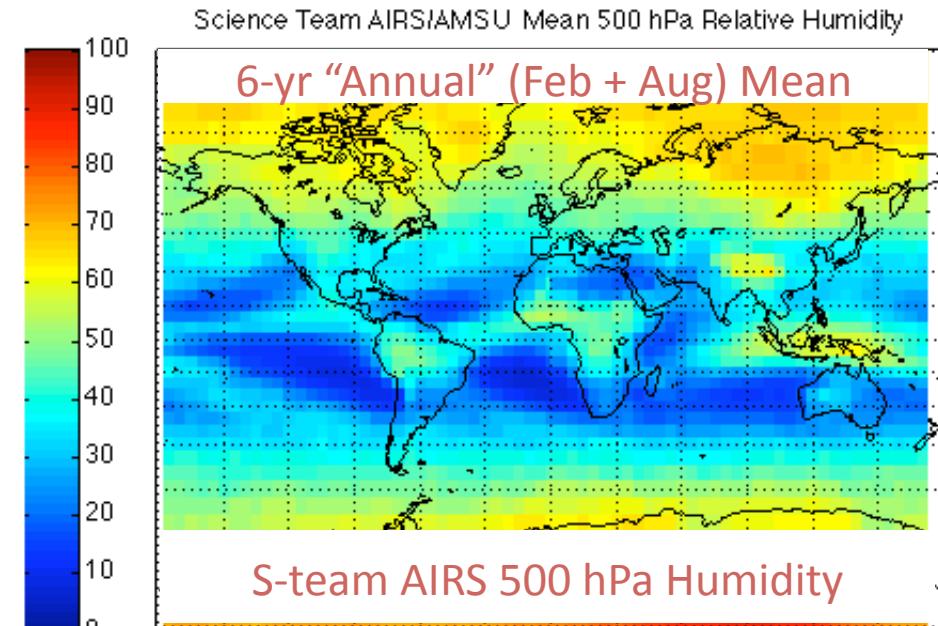
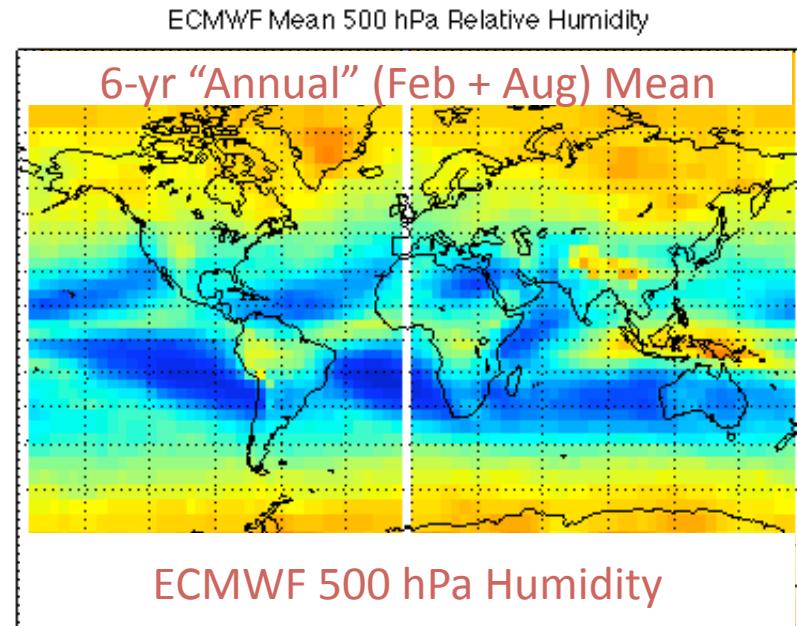
Dual Regn AIRS/CLARREO, ScTm AIRS+AMSU, ECMWF (2003-2008)



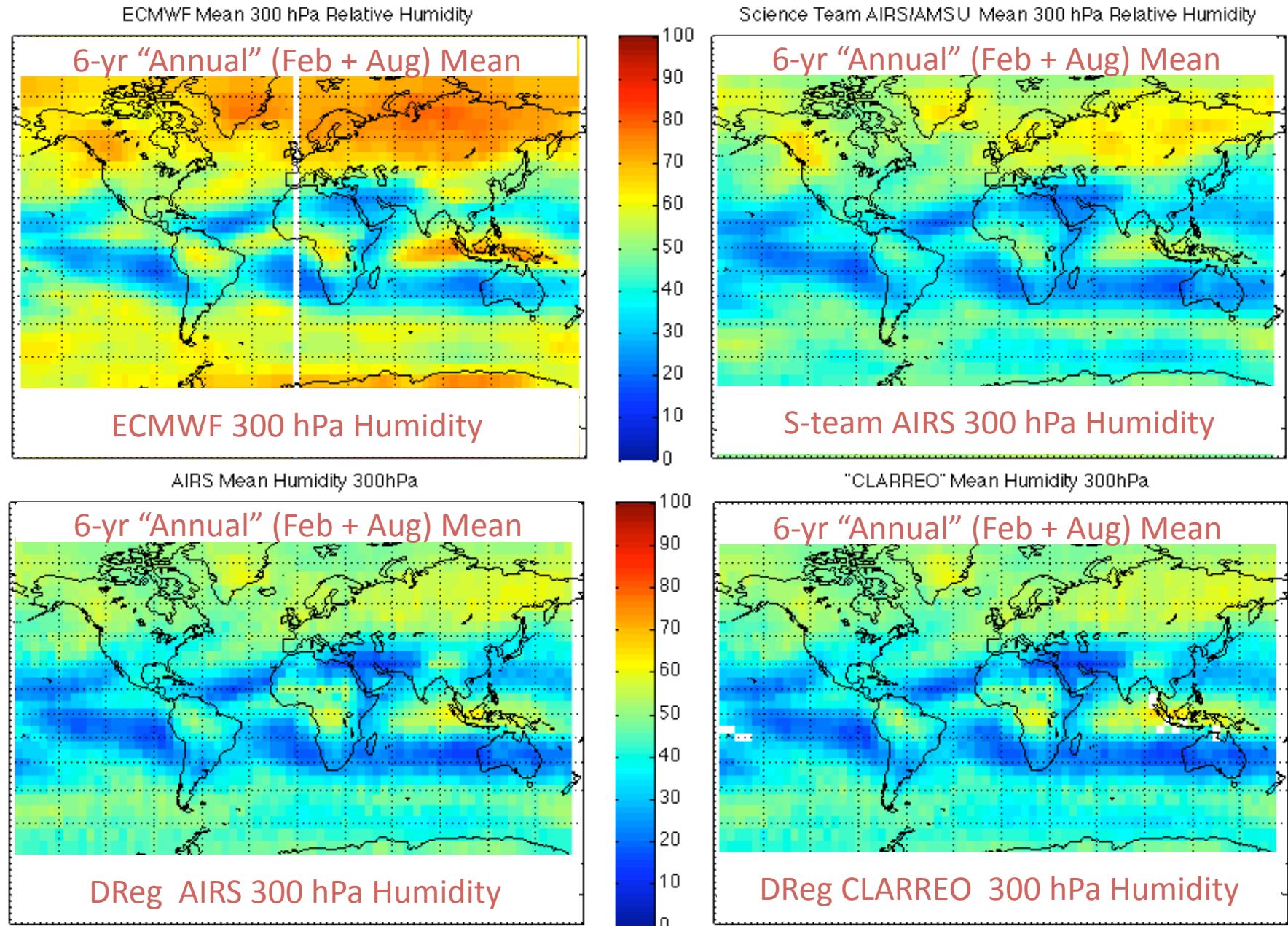
Dual Regn AIRS/CLARREO, ScTm AIRS+AMSU, ECMWF (2003-2008)



Dual Regn AIRS/CLARREO, ScTm AIRS+AMSU, ECMWF (2003-2008)

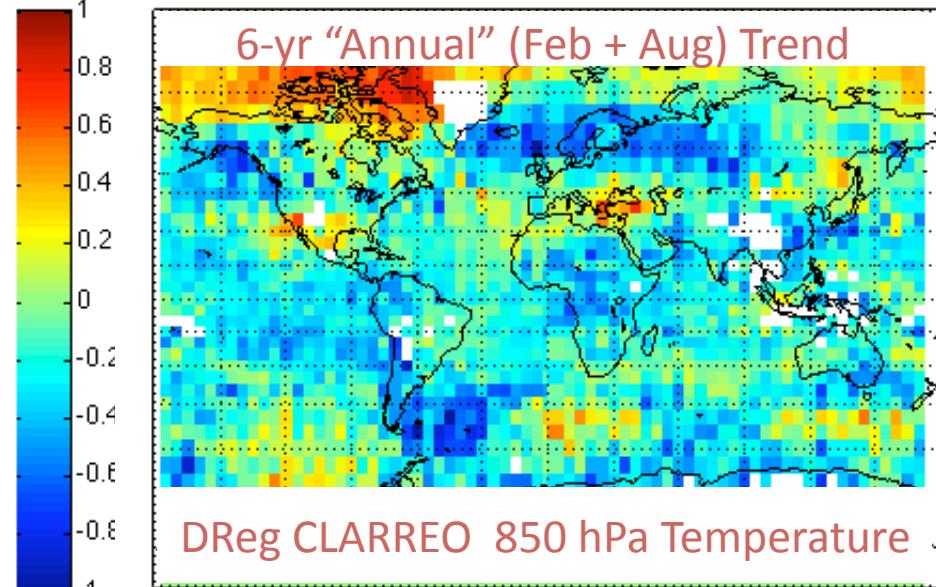
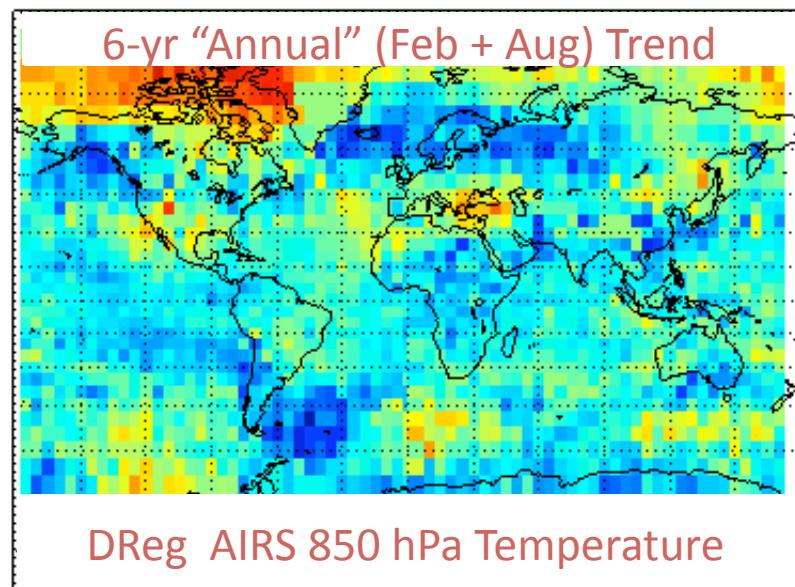
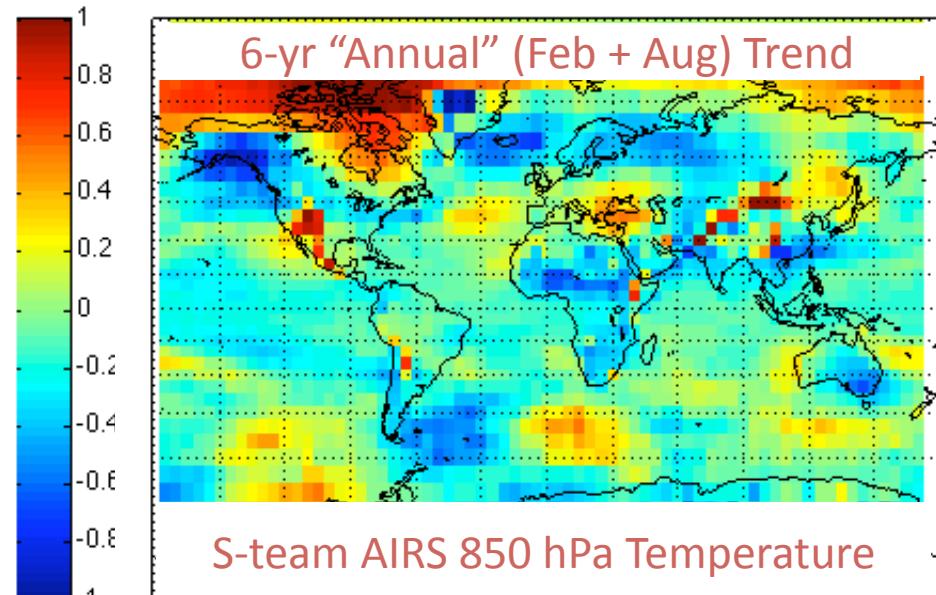
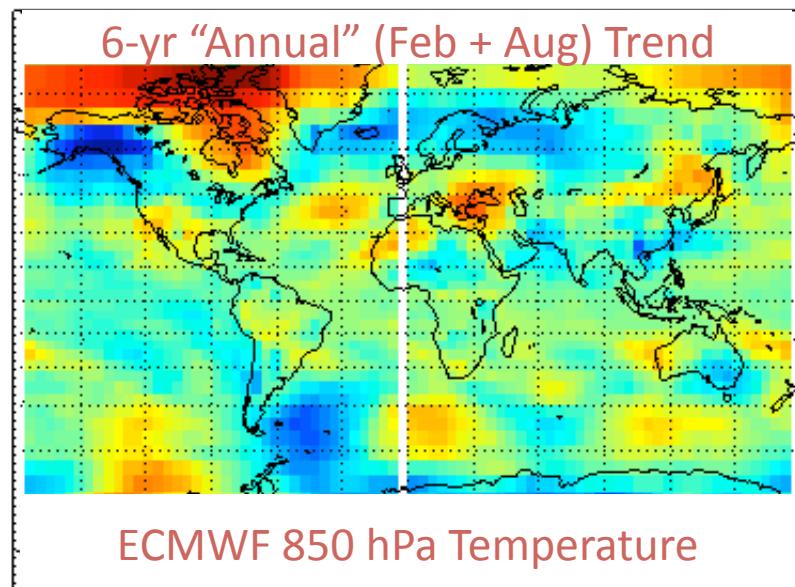


Dual Regn AIRS/CLARREO, ScTm AIRS+AMSU, ECMWF (2003-2008)

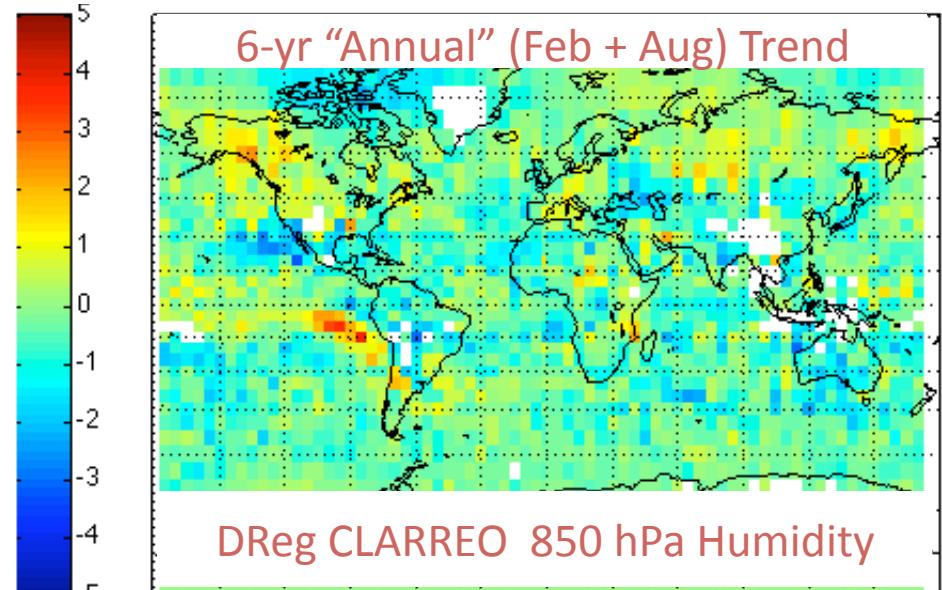
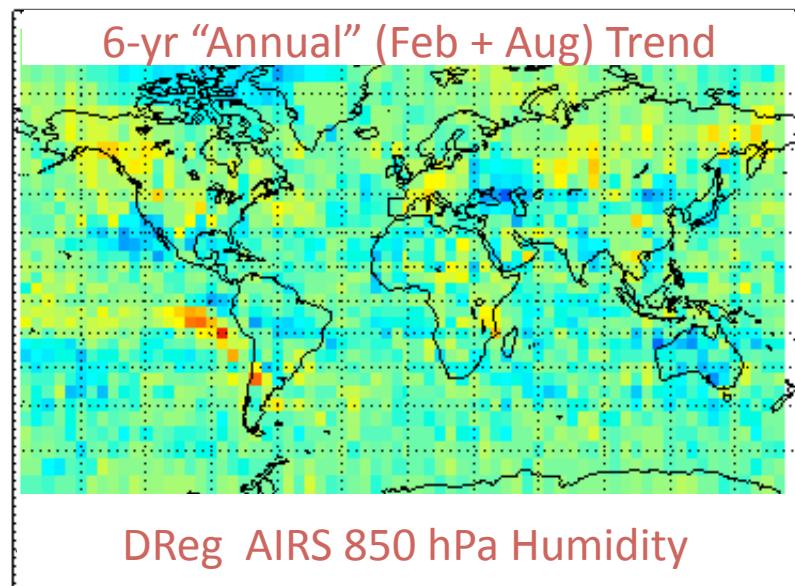
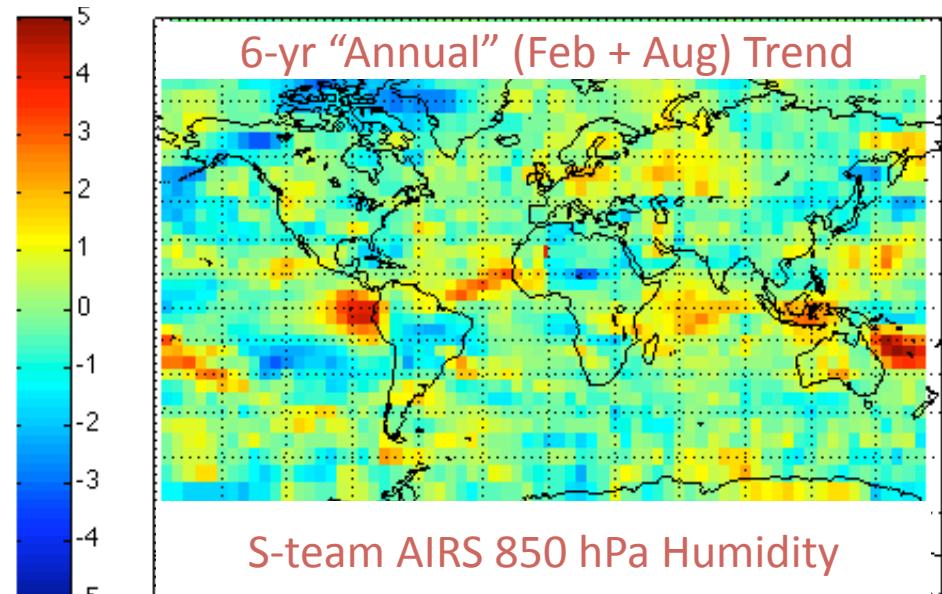
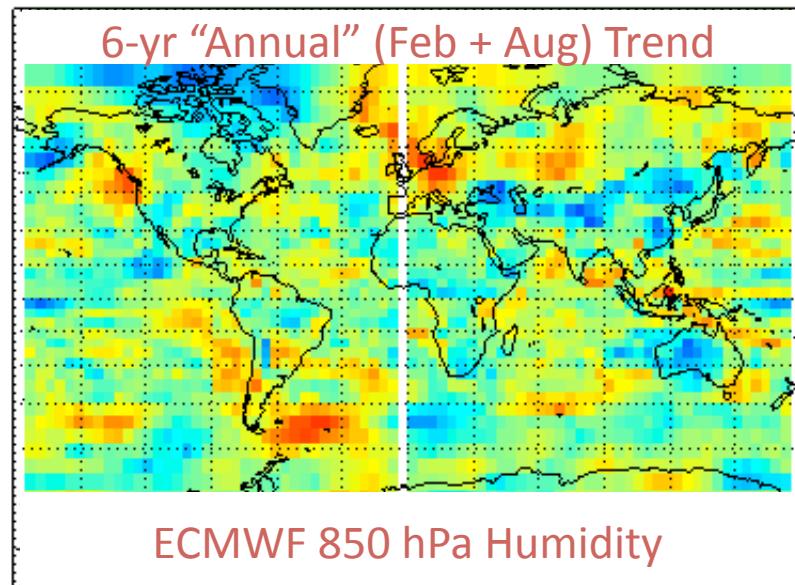


Trend Comparisons

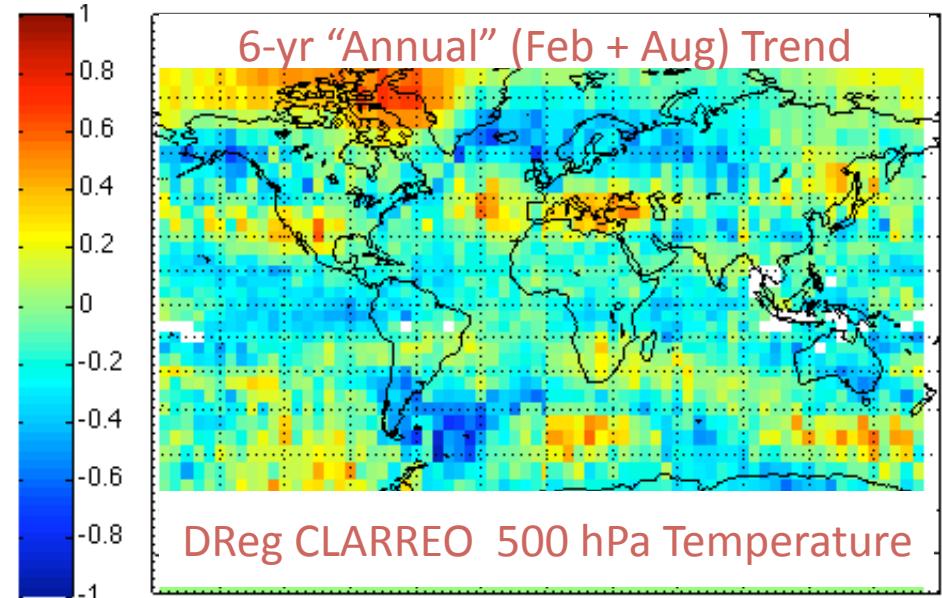
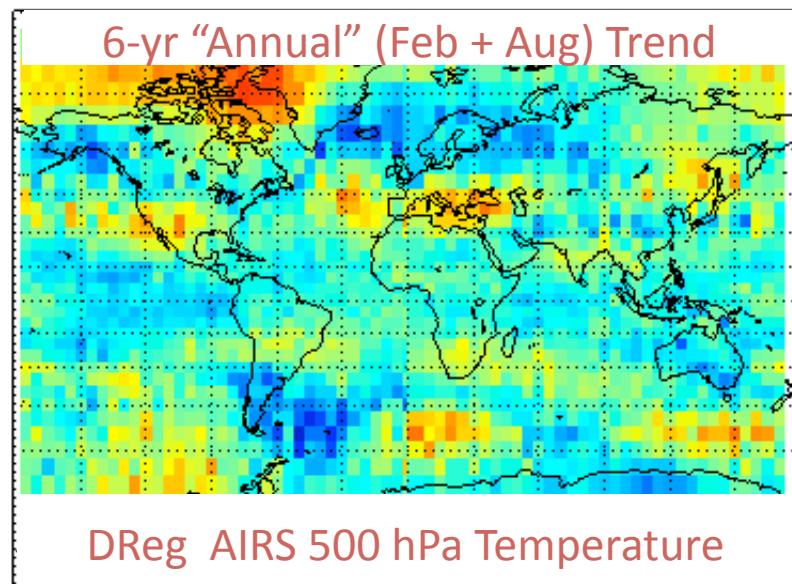
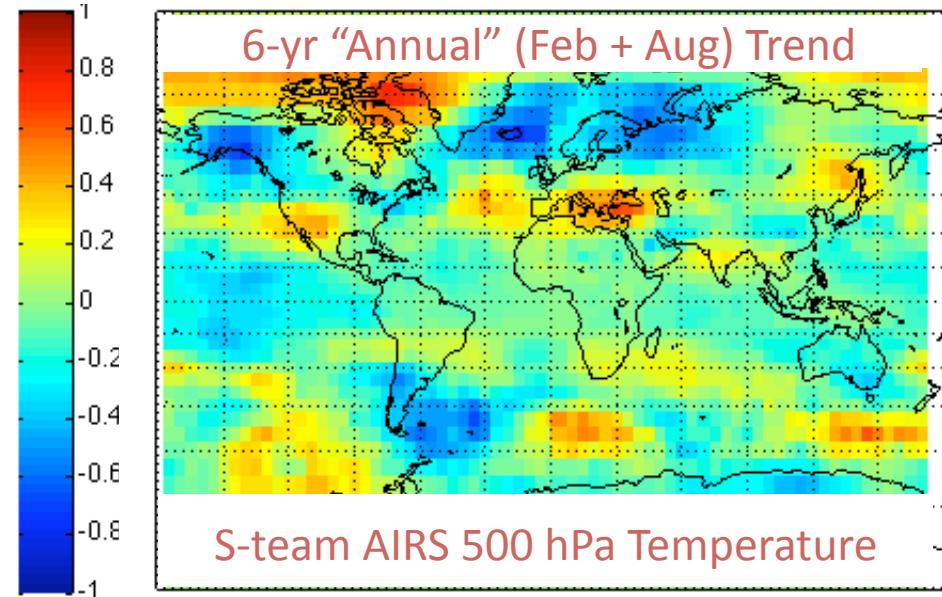
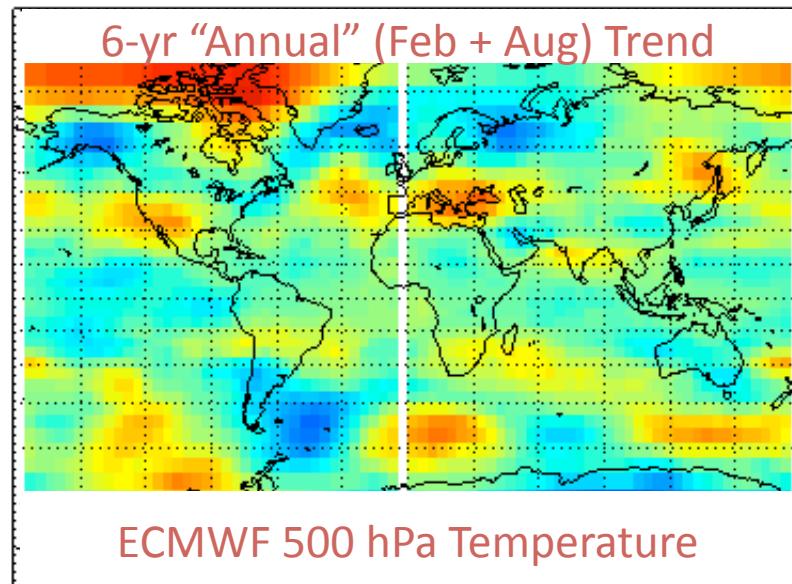
6-Year “Annual” Trend (2003-2008)



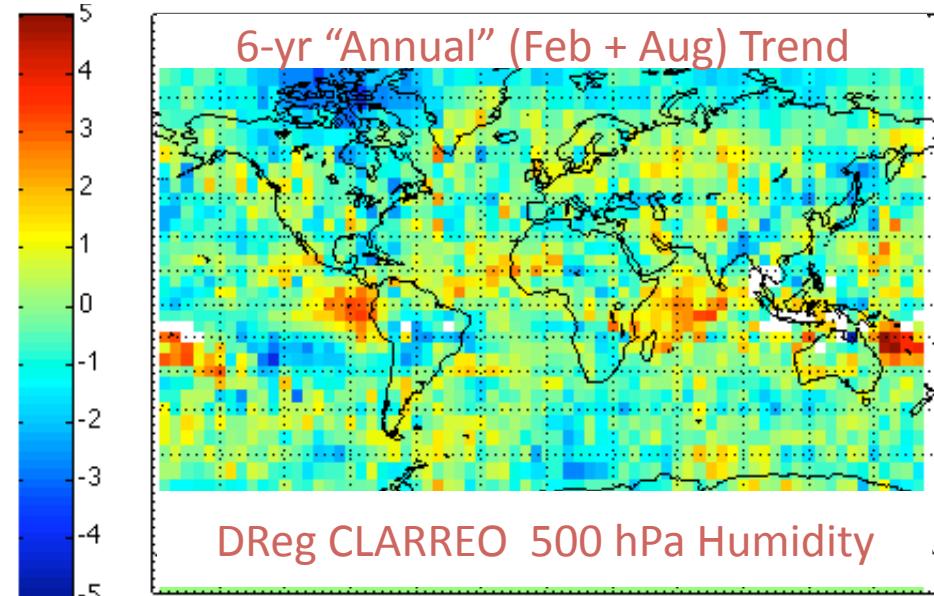
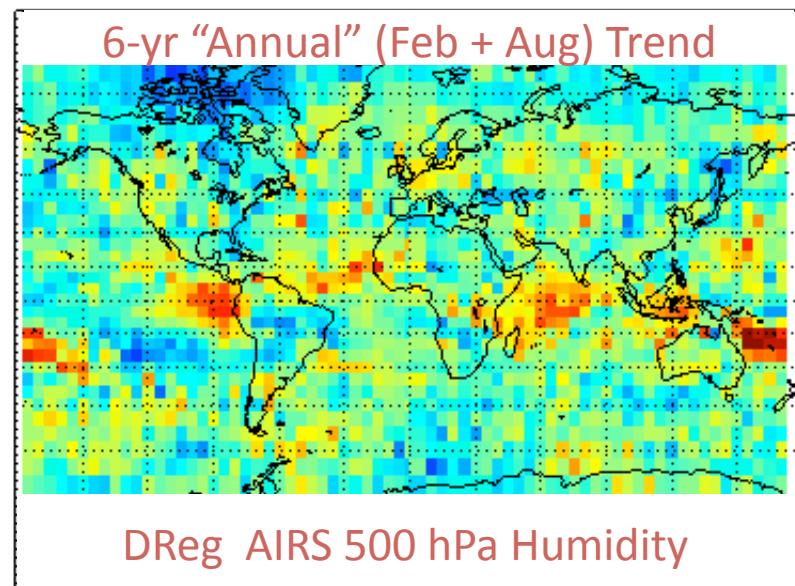
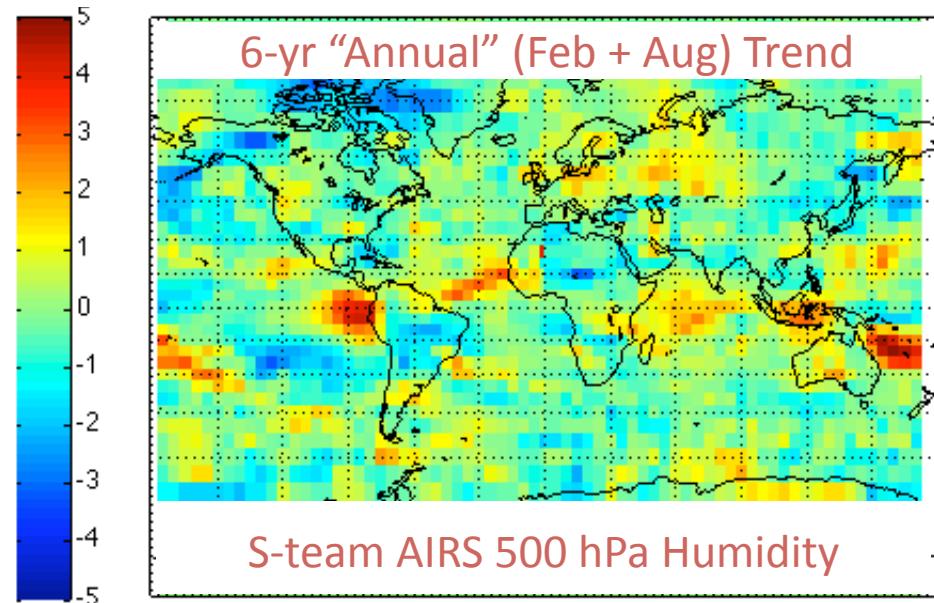
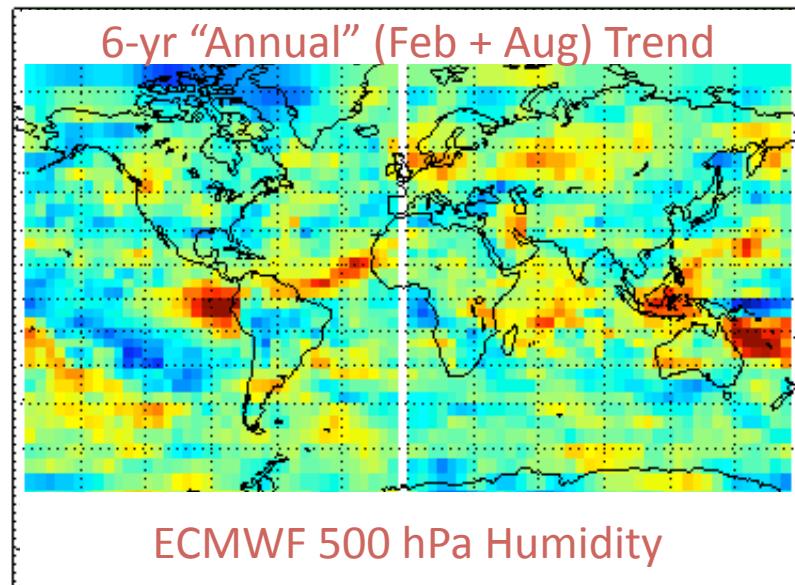
6-Year “Annual” Trend (2003-2008)



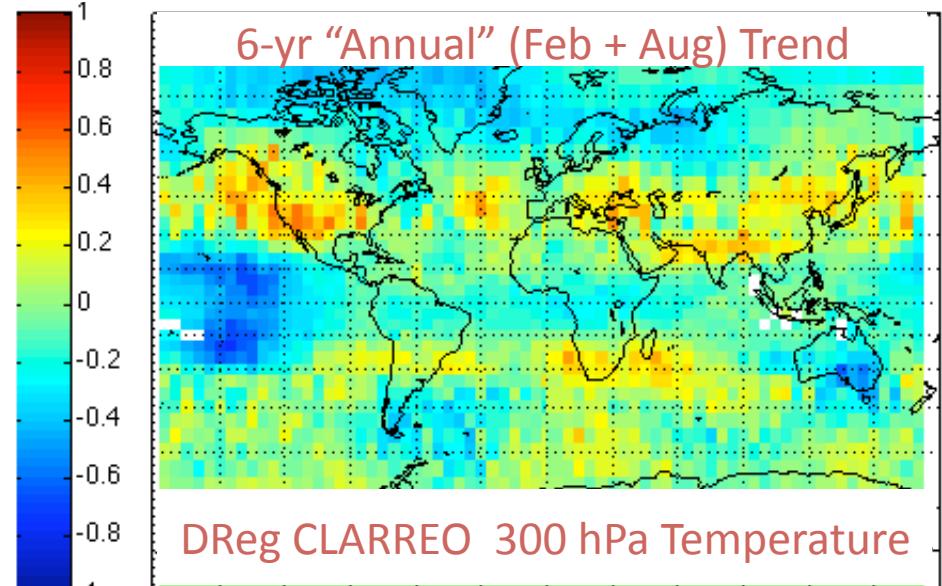
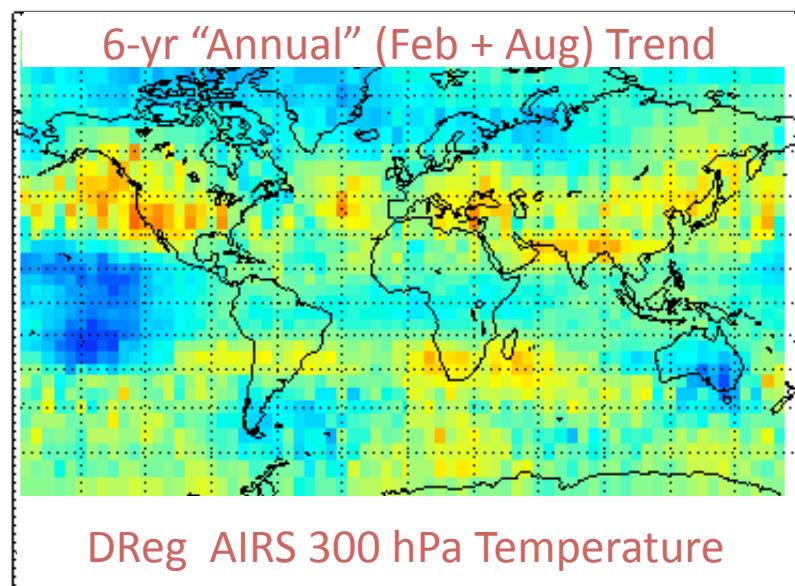
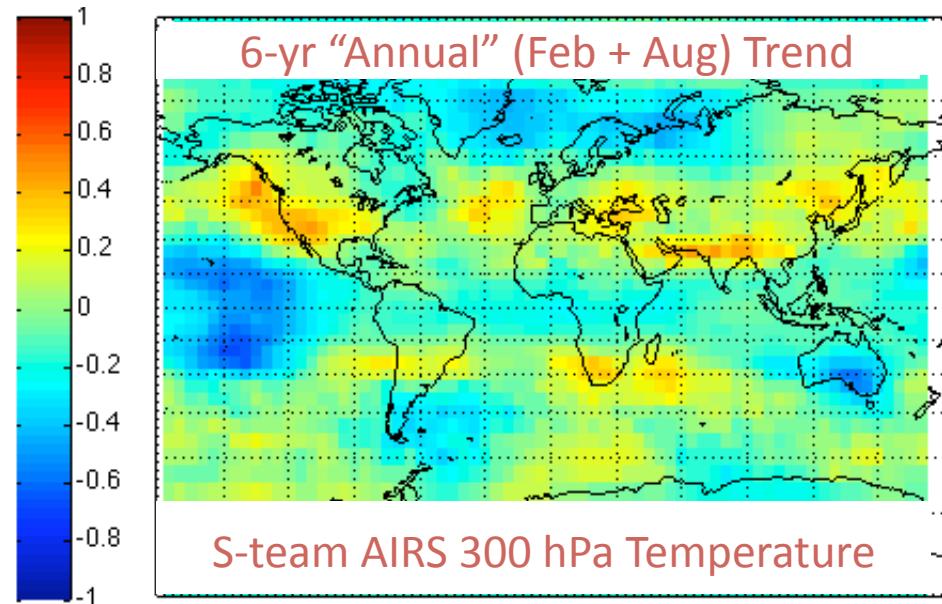
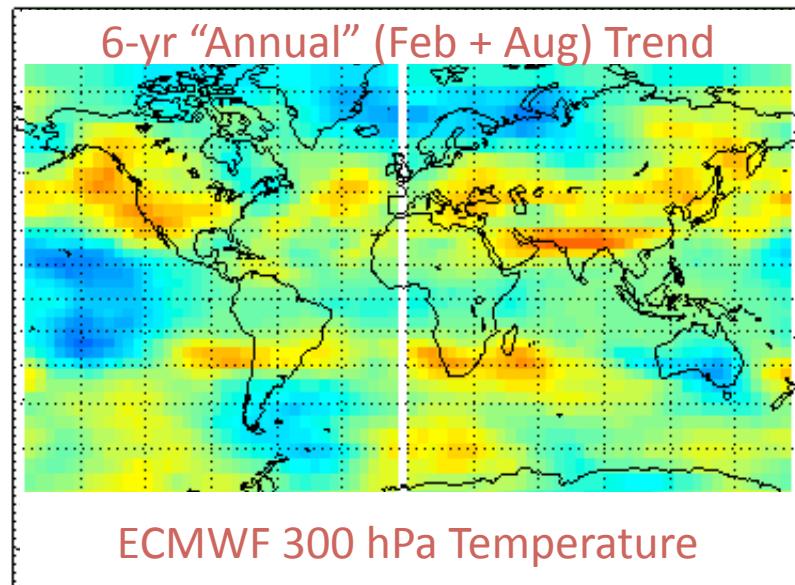
6-Year “Annual” Trend (2003-2008)



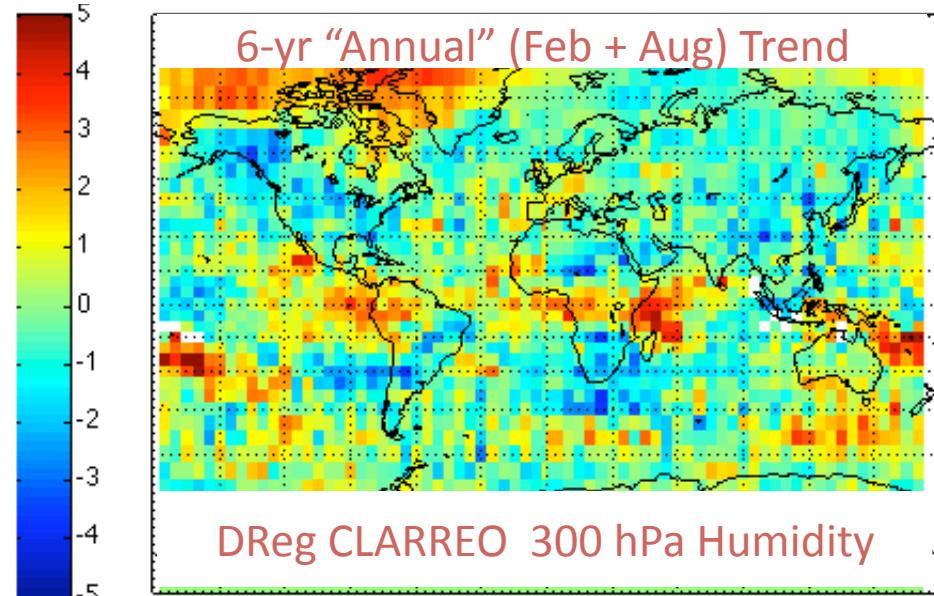
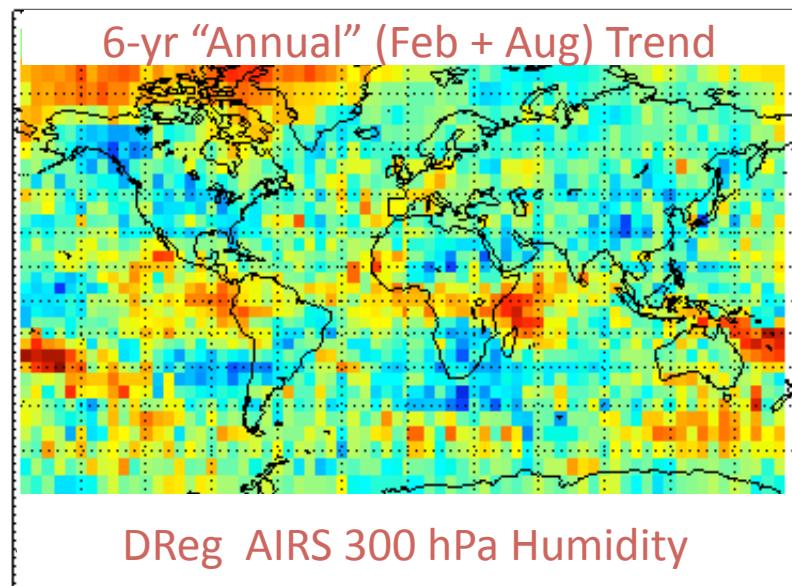
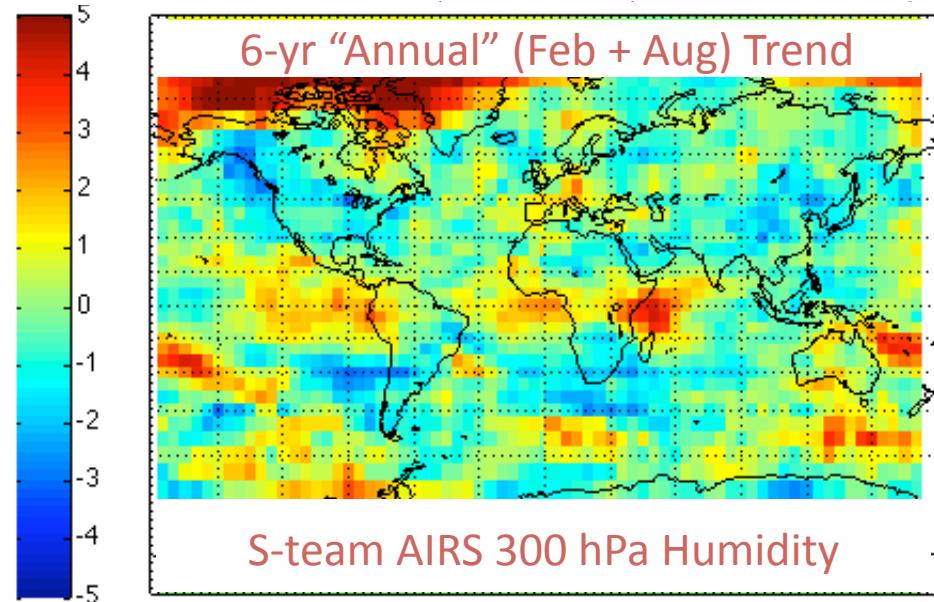
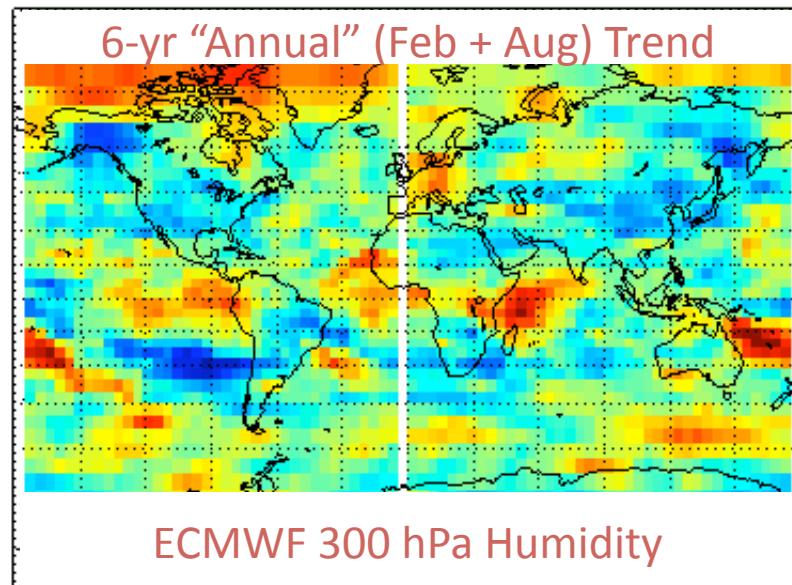
6-Year “Annual” Trend (2003-2008)



6-Year “Annual” Trend (2003-2008)



6-Year “Annual” Trend (2003-2008)



6-Year “Annual” Trend (2003-2008)

